Honeywell

MICRO SWITCH
Sensing and Control

September 1998

Environmental Condition Sensors

Catalog 15

- Pressure
- Force
- Airflow
- Temperature
- Humidity

This information available on CD-ROM and the World Wide Web!

How to Use This Catalog

CATALOG PURPOSE
This catalog is intended to familiarize users with the broad MICRO SWITCH product offering and provide ordering information for the most popular listings.

The products described on the following pages are representative of the thousands of pressure, temperature and microbridge air flow sensors manufactured and distributed worldwide by MICRO SWITCH. Almost all of the catalog listings given are preferred listings and normally will be off-the-shelf-delivery.

USING THE CATALOG
This section on "How to Use The Catalog" will help you make a logical choice in selecting the best product for a particular application need. It allows a user familiar with our products to quickly locate the exact page the needed product catalog listings are on. For those unfamiliar with MICRO SWITCH products, a logical sequence is given to help the user pick the appropriate product for their application need.

By taking a few minutes to familiarize yourself with the catalog organization, you will quickly locate the product you need.

REFERENCE DATA
Need reference and application information — (see page 101).

Definitions of terms will familiarize you with terminology used throughout the catalog — (see page 148).

MOUNTING DIMENSIONS
Mounting dimensions are shown in each product section in English and metric equivalents. These dimensions are for reference only. For exacting layout work, request an engineering drawing from your nearest MICRO SWITCH Sales Office.

Many of the most popular pressure sensors, temperature sensors and mass air flow sensors are included in the catalog. Many others, developed for special needs, are not. For more information or prices, call our 800 number.

SELECTION
On page 1 you can see representative products found in the catalog. The various sensor types and offerings are highlighted below. The Table of Contents directs users to the main parts of the catalog.

1. **24PCAFA2F**
   If you have a catalog listing, use the alpha-numeric index/page number starting on page 155.

2. **AMPLIFIED PRESSURE SENSORS**
   If you know the type of sensor you're looking for, use the Table of Contents on page 3 to find the page number.

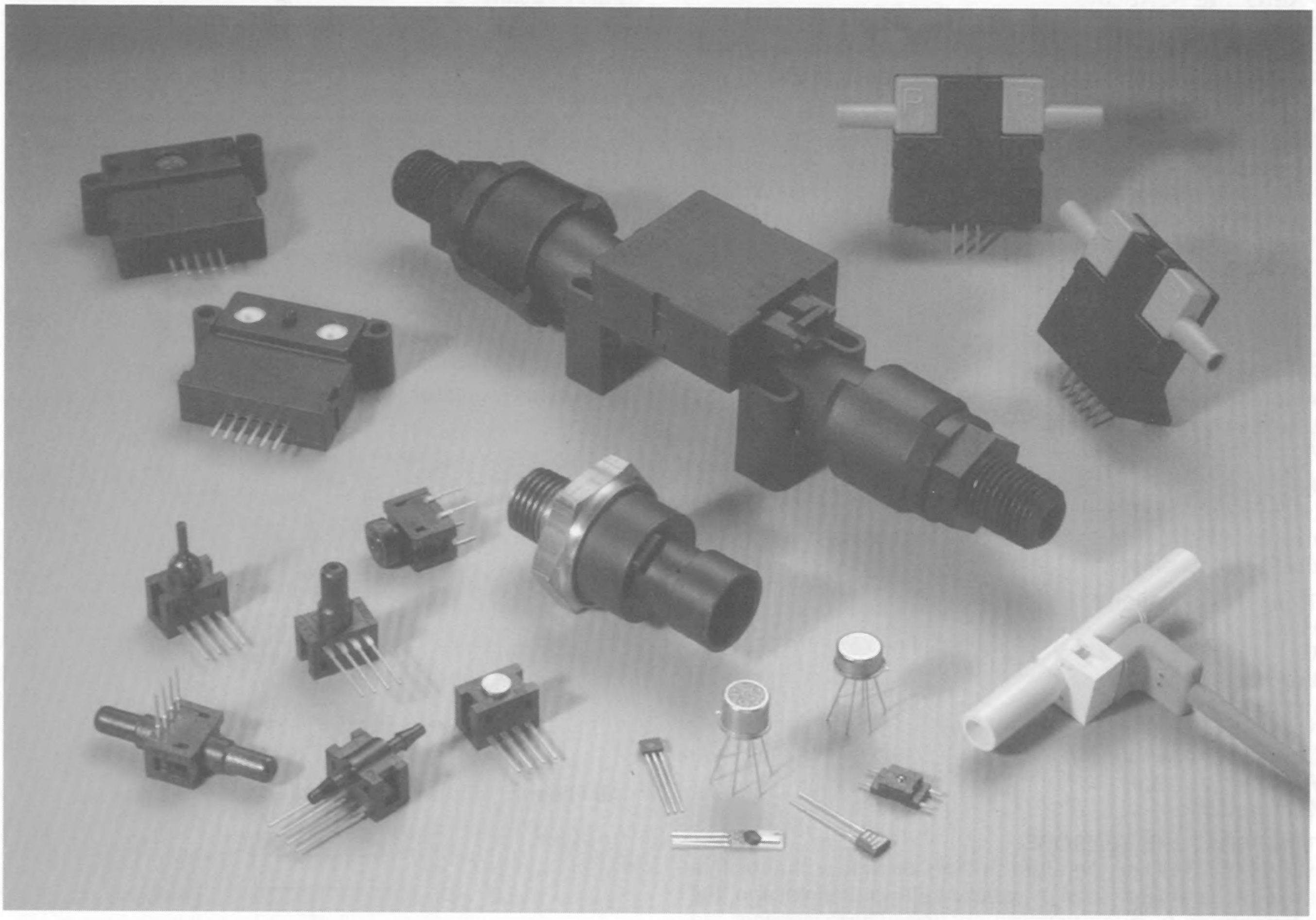
3. **USE SELECTION GUIDE**
   If you're not familiar with the products or need more information, a detailed selection guide begins on page 4. Here photos for each product type and important selection factors are given to help determine and select the best product for the application.
   They include:

- Physical description—size, pressure range, construction, etc.
- Pressure ranges
- Electrical parameters—supply, output, etc.
- Termination
- Output level

In many cases, more than one product may work. For the most cost-effective solution, compare prices and consider alternatives. Remember, end cost includes initial product price, plus installation, plus service.

> **⚠ WARNING**
> **MISUSE OF DOCUMENTATION**
> - The information presented in this catalog is for reference only. Do not use this document as product installation information.
> - Complete installation, operation and maintenance information is provided in the instructions supplied with each product.
>
> **Failure to comply with these instructions could result in death or serious injury.**

ENVIRONMENTAL CONDITION SENSORS
Pressure, Force, Airflow, Temperature and Humidity



Pressure sensors, force sensors and airflow sensors are all developed around semiconductor technology. Each pressure sensor contains a silicon chip with an integral sensing diaphragm and four piezoresistors. Pressure applied on the diaphragm causes it to flex, changing the resistance. This causes a low level output voltage proportional to pressure.

Airflow sensors contain a thin-film, thermally isolated bridge structure containing heater and temperature sensing elements. The bridge structure provides a sensitive and fast response to the flow of air or other gas over the chip.

Temperature sensors provide a change in a physical parameter such as resistance or output voltage that corresponds to a temperature change. The sensors, in small package sizes, provide accurate linear output and interchangeability without recalibration.

Absorption based humidity sensors provide both temperature and %RH (Relative Humidity) outputs. On-chip signal processing ensures linear voltage output versus %RH. Sensor laser trimming offers ±5% RH accuracy, or 2% RH accuracy with calibration. Chemically resistant packages tolerate harsh environments in ranges of −40°C to 85°C (−40°F to 185°F).

NOTE:
Before placing an order, please check the date on the front of this catalog. If it's more than a year old, we may have a more up-to-date catalog available.

⚠ WARNING

PERSONAL INJURY

- DO NOT USE these products as safety or emergency stop devices, or in any other application where failure of the product could result in personal injury.

Failure to comply with these instructions could result in death or serious injury.

Temperature error is calculated with respect to 25°C and expresses the deviation that could occur as temperature is raised or lowered to limits indicated.

Typical (as used herein) refers to the target value or where a range is given, represents an estimate of where 2/3 of the total population of several production runs would be.

Span is the algebraic difference between end points (output at null and full pressure). Span will vary proportionately with supply voltage (sensor not internally regulated).

To assure you have the latest information on our product offering, call the MICRO SWITCH Application Center at 1-800-537-6945. They can tell you if your catalog is current, and they'll be happy to send you a new one if it's not. They'll also help immediately to confirm the validity of the product listing you'd like to order.

Typical Applications

PRESSURE SENSORS

Pressure sensors are used in applications which require precise pressure measurement, where the benefits of repeatability, low hysteresis, and long term stability are important.

Typical Applications

Medical equipment
Lie detectors
Automatic bottle testing machinery
Digital barometers
Automatic check sorters
Computer and business equipment
Flight data recorders
Landing gear
Light aircraft instrumentation
Pressure/current transmitters
Automatic plasma control systems
Liquid level measurement
Automatic heating, ventilating, air conditioning systems

MICROBRIDGE MASS AIRFLOW SENSORS

Microbridge mass airflow sensors operate on the theory of heat transfer due to mass airflow directed across the surface of the sensing element.

Typical Applications

HVAC – damper control
Gas analyzers
Low vacuum control
Process control
Medical respirators and spirometers
Demand oxygen supply
Anesthesia control
Gas metering

TEMPERATURE SENSORS

MICRO SWITCH temperature sensors provide a change in a physical parameter such as resistance or output voltage that corresponds to a temperature change. These sensors are suitable for applications that require small package size, accuracy, linear outputs, and interchangeability.

Typical Applications

HVAC – room, duct and refrigerant equipment
Motors – overload protection
Electronic circuits – semiconductor protection
Electronic assemblies – thermal management, temperature compensation
Process control – temperature regulation
Automotive – air and oil temperature
Appliances – heating and cooling temperature

HUMIDITY SENSORS

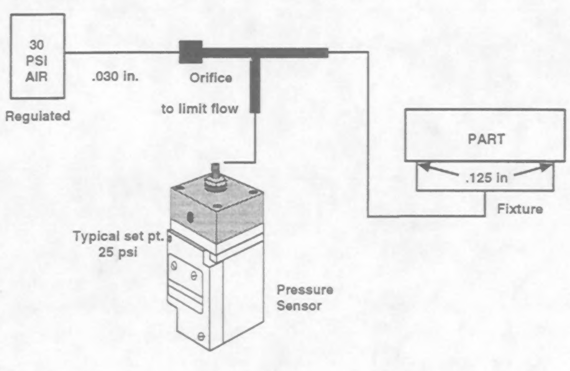
Relative Humidity sensors combine thermally connected humidity and temperature sensing elements. These sensors are ideal for measuring dew point and other absolute moisture terms. Designed for OEM use, monolithic integrated circuit humidity sensors provide a linear voltage output for direct input to controllers or other devices.

Typical Applications

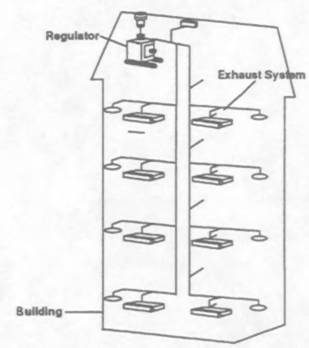
Refrigeration
Drying
Meteorology
Battery-powered systems
OEM assemblies

MICRO SWITCH pressure sensors are not necessarily designed or manufactured for use as a "critical device" as those terms are defined in the Medical Device Subchapter contained in the Food and Drug Administration Rules, 21CFR800.

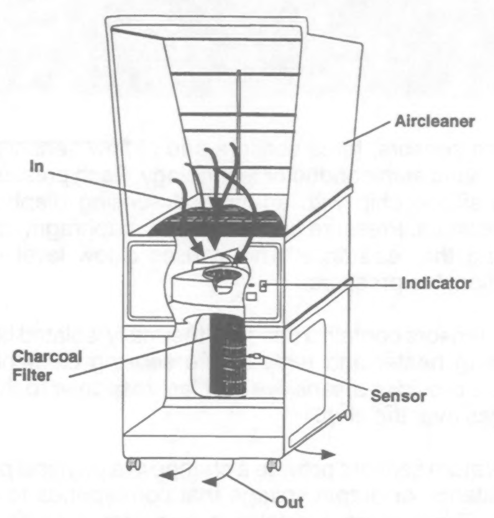
Part Positioning



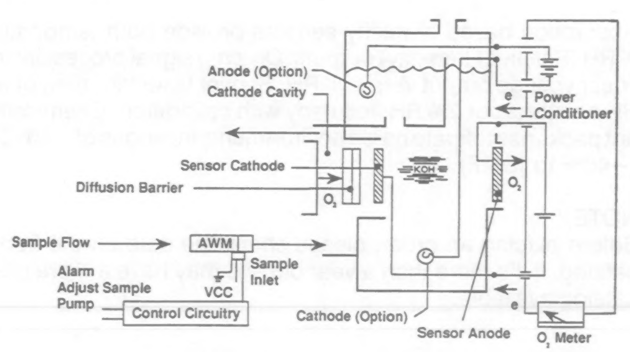
Pressure Regulator



Air Cleaner (Graphic Industry)



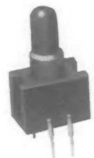
Gas Analyzer

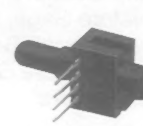


Environmental Condition Sensors
Pressure, Force, Airflow, Temperature and Humidity

Table of Contents

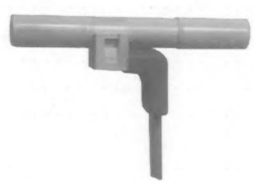
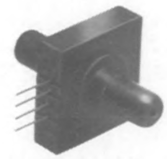
Pressure Sensor Selection Guide





UNAMPLIFIED SENSORS

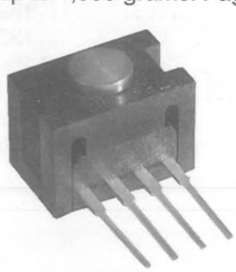
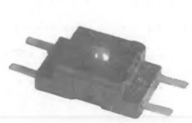
	22PC Series	20PC Series 24PC Series	26PC Series
	Page 10	Page 11	Page 15
Pressure Range (psi)	1, 15, 100	0-0.5, 0-1, 0-5, 0-15, 0-30, 0-100, 0-250	0-1, 0-5, 0-15, 0-30, 0-100
Pressure Measurement Type	Gage	Gage, Differential & Absolute	Gage & Differential
Construction	Thermoplastic	Thermoplastic	Thermoplastic
Termination	PCB	PCB	PCB
Output Level	mV	mV	mV
Calibrated Null & Span	No	No	Yes
Temperature Compensated	No	No	Yes

UNAMPLIFIED SENSORS

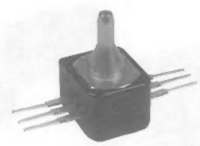
	Flow-through 20PC Series 24PC	26PC	170PC Series
	Page 21	Page 23	Page 29
Pressure Range (psi)	0.5, 1, 5, 15, 30, 100, 250		0-7″ H_2O, 0-14″ H_2O, 0-28″ H_2O
Pressure Measurement Type	Gage		Differential & Gage
Construction	Thermoplastic		Thermoplastic
Termination	PCB, Wire harness		.020″ x .014″ PCB
Output Level	mV		mV
Calibrated Null & Span	No	Yes	Yes
Temperature Compensated	No	Yes	Yes

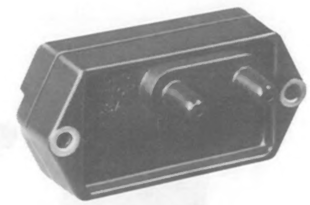
FS Series Force Sensors measure forces up to 1,500 grams. Page 61.

Pressure Sensor Selection Guide

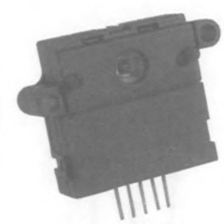
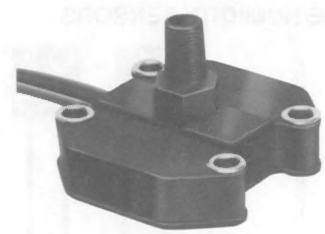
SIGNAL CONDITIONED AMPLIFIED SENSORS





	40PC Series Page 31	4000PC Series Page 34	140PC Series Page 37	160PC Series Page 41
Pressure Range (psi)	± 50 mm Hg, 15, 100, 150, 250	± 50 mm Hg, 15, 100, 150, 250	0-1, 0-2, 0-5, 0-5.8, 0-10, 0-30, (141/142PC) ±1, ±2.5, ±5, ±15 (143PC)	0-27.68″ H_2O (161/162PC) ±2.5, 5″ H_2O (163PC) 0-5, 0-10″ H_2O (164PC)
Pressure Measurement Type	Gage	Gage	Absolute, Differential, Gage & Vacuum Gage	Differential, Gage & Vacuum Gage
Construction	Thermoplastic, stainless steel	Thermoplastic, stainless steel	Thermoplastic Housing	Thermoplastic Housing
Termination	PCB	Connector, wire harness	.010″ x .020″ PCB	.010″ x .020″ PCB
Output	Volts	Volts	Volts	Volts
Calibrated Null & Span	Yes	Yes	Yes	Yes
Temperature Compensated	Yes	Yes	Yes	Yes

SIGNAL CONDITIONED AMPLIFIED SENSORS

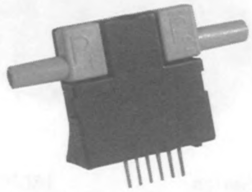
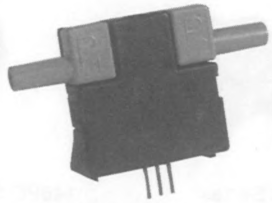
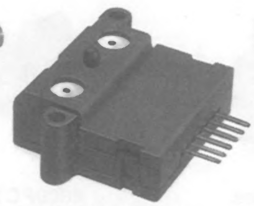
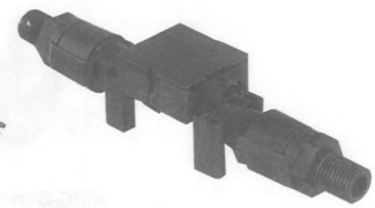
	180PC Series Page 45	189PC Series Page 49	240PC Series Page 51	249PC Series Page 55
Pressure Range (psi)	0-5, 0-15, 0-30 (184/185PC) ±2.5, ±5, ±15 (186PC)	0-15, 0-100, 0-150	0 to -15, (241PC) 0-15, 0-30, 0-60, 0-100, 0-150, 0-250 (242PC) ±15 (243PC)	3-15, 0-100, 0-250
Pressure Measurement Type	Absolute, Gage, Differential	Gage	Gage & Vacuum Gage	Gage
Construction	Thermoplastic Housing	Thermoplastic Housing	Die-cast Aluminum Housing	Die-cast Aluminum Housing
Termination	.010″ × .020″ PCB	0.025″ Square PCB	300mm (12 in.) long #18AWG leadwire	300mm (12 in.) long #18AWG leadwire
Output	Volts	Volts	Volts	mA
Calibrated Null & Span	Yes	Yes	Yes	Yes
Temperature Compensated	Yes	Yes	Yes	Yes

SSP Series pressure sensors provide pressure-to-current or digital setpoint output in a rugged die cast housing. Interchangeable mounting with MICRO SWITCH HDLS limit switches. Page 57.

For more information on these solid state pressure sensors, contact your local MICRO SWITCH sales office or Application Center.

Mass Airflow & Temperature/Humidity Sensor Selection Guide

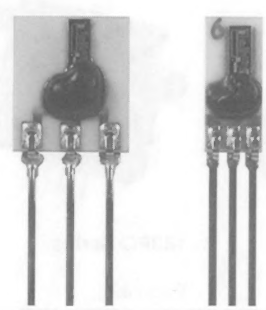
Low Flow | **High Flow**

	AWM2000 Series	AWM3000 Series	AWM40000 Series	AWM5000 Series
	Page 68	Page 71	Page 76	Page 79
Flow Range (sccm)*	±30, ±200, ±1000	0-30, 0-200, 0-1000	±25, ±1000 ±6 SLPM**	0-5, 0-10, 0-15, 0-20
Pressure Range	±4″ H_2O (10mBar)	+2″ H_2O (5mBar)	---	---
Excitation Voltage	10 V	10 V	10 V	10 V
Output	mV	V & mA	mV & V	V
Temperature Range	−25 to +85°C	−25 to +85°C	−25 to +85°C	−20 to +70°C
Termination	0.025″ square PCB	0.025″ square PCB	0.025″ square PCB	---
Response Time	3 msec max.	3 msec max.	3 msec max.	60 msec max.
Max. Common Mode Pressure	25 psi	25 psi	150 psi	50 psi

*** sccm: Standard cubic centimeters per minute.**
**** SLPM: Standard liters per minute.**

TEMPERATURE/HUMIDITY SENSORS



	TD/HEL Series	HIH/Humidity Sensors
	Page 83	Page 95
Operation	Temperature changes	Humidity changes
Supply Voltage	4-9 VDC	4-9 VDC
Construction	Molded plastic package	Ceramic hybrid circuit
Termination	Printed circuit board	Printed circuit board Surface mount
Operating Speed	≈ 1 to 4 seconds	≈ 1 to 4 seconds
Temperature Range	Depends on sensor	Depends on sensor
Output Type	Linear	Linear

Honeywell

Pressure Sensor Application Data Sheet

Business Data

Customer	SIC No. or Industry	Sales Engineer
	Contact	Date

Customer Project ____________

Sensor Application ____________

	Qty.	When	Target Price
Initial Samples			
Initial Production			
Prod. 1st Year			
Prod. 2nd Year			
Prod. 3rd Year			

Competition: Who ____________

Direct: Model No. ____________

Price ________ Qty. ________

How is function accomplished now? ____________

Application Checklist

A. Pressure Requirements

☐ Pressure range ________ to ________

☐ Overpressure ________

☐ Sensor type ________

1. Absolute-input pressure is measured in relation to a perfect vacuum
2. Gage-input pressure is greater than and measured in relation to atmospheric pressure
3. Vacuum gage-input pressure is less than and measured in relation to atmospheric pressure
4. Bi-directional-input pressure can be greater or less than atmospheric pressure and is measured in relation to atmospheric pressure
5. Differential – one input pressure is measured in relation to another input pressure

Common mode pressure ________

B. Accuracy Requirements

☐ Error tolerance at null pressure (Room Temp) ________

☐ Error tolerance at full pressure (Room Temp) ________

☐ Linearity error tolerance ________

☐ Repeatability and Hysteresis error tolerance ________

☐ Temperature shift error tolerance over a range of ________ °C to ________ °C

1. Tol. at null pressure ________
2. Tol. at full pressure ________

☐ Other ________

C. Electrical Requirements

☐ Output Signal ________

☐ Excitation ________

☐ Other ________

D. Package Requirements

☐ Housing ________

☐ Termination ________

☐ Other ________

E. Application Requirements

☐ Media* Compatibility ________

1. Common Name ________
2. Chemical Identification ________
3. Chemical Concentration ________
4. Operating Temp Range ________ °C to ________ °C

*For differential, specify both

☐ Environmental Conditions

1. Operating Temp. Range ________ °C to ________ °C
2. Storage Temp. Range ________ °C to ________ °C
3. Other ________

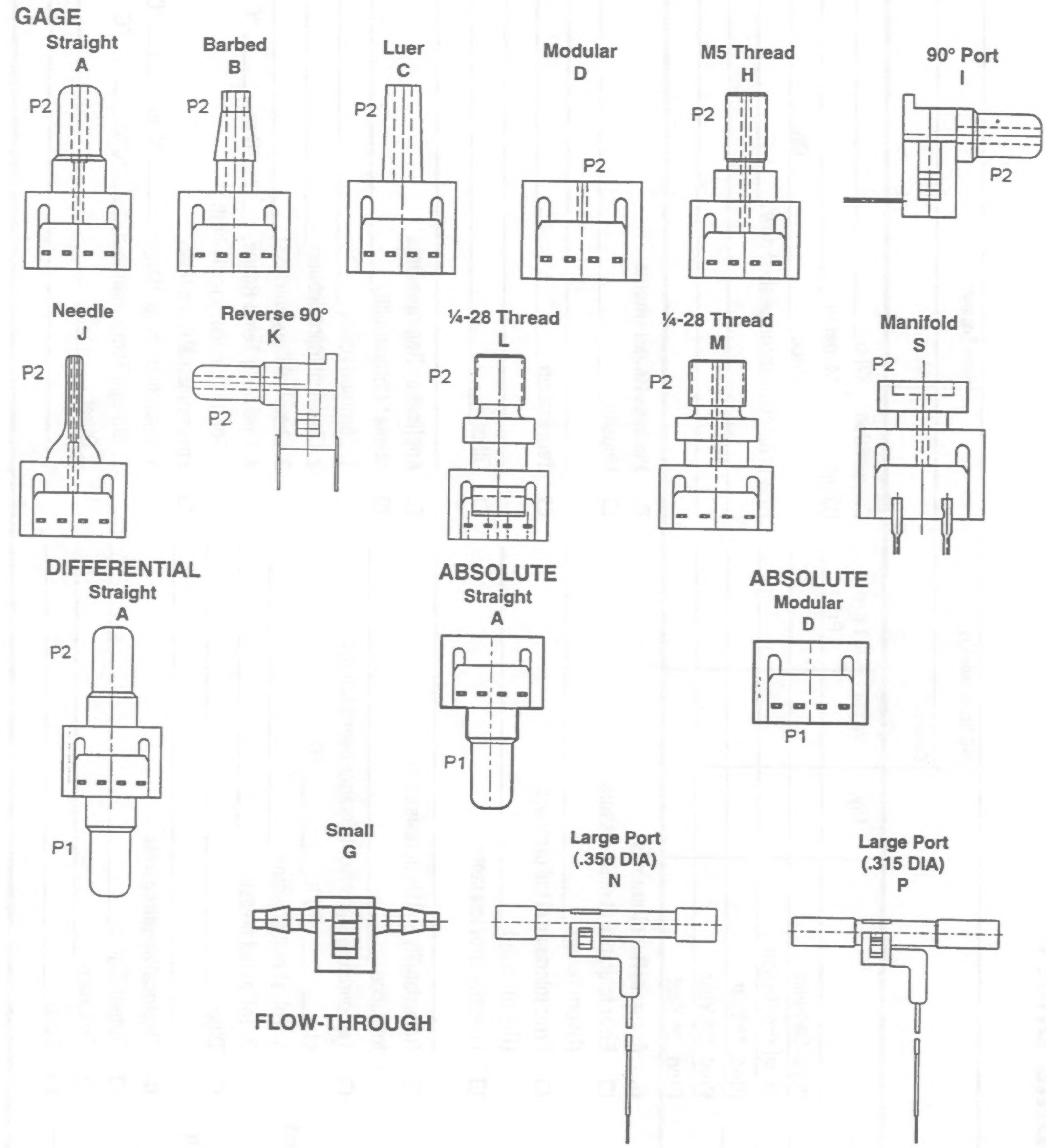
Notes ____________

Action Requested

☐ Information Only ☐ Advise Feasibility ☐ Quote Pricing for Quantities from ________ to ________ ☐ Provide delivery time for ________ pieces

☐ Other ____________

FO-63775-C



20PC Series Catalog Number System

2 Product Family	4 Circuit Type	PC Pressure Transducer	A Pressure Range	F* Type of Seal	A Type of Port	2 Termination Style	G Pressure Measurement
2 20PC Family	**2** Noncompen-sated low cost **4** Noncom-pensated **6** Compensated		**A** 1 psi **B** 5 psi **C** 15 psi **D** 30 psi **E** 0.5 psi **F** 100 psi **G** 250 psi **J** 38 psi **K** 38 psi (passivated**)	**E** EPDM **F** Fluorosilicone **N** Neoprene **S** Silicone	**A** Straight **B** Barbed **C** Luer **D** Modular **H** M5 Thread **I** 90° Port **J** Needle **K** Reverse 90° **L** 1/4-28 UNF w/Cable Lock **M** 1/4-28 UNF w/o Cable Lock **N** Large Flow-Through **G** Small Flow-Through **P** Large Flow-Through **S** Manifold Mount	**1** 1 x 4 (.400″) **2** 2 x 2 **5** Wire harness (Flowthrough) **6** 1 x 4 (.600″)	**G** Gage **D** Differential **A** Absolute

*Other media seals may be available
**P2 side of die coated for environmental and dielectic protection.

NOTE: For identification purposes only: not all catalog listings are established. Please refer to the Order Guides, or contact the MICRO SWITCH Application Center at the 800 number.

Unamplified

22PC SERIES ORDER GUIDE

Catalog Listing	Pressure Range psi	Span, mV			Sensitivity mV/psi Typ.	Overpressure psi, Max.
		Min.	Typ.	Max.		
22PCA Type	1.0	25	42	59	42	20
22PCC Type	15	156	225	294	15	45
22PCF Type	100	147	225	303	2.3	200

SENSOR SELECTION GUIDE

2 Product Family	2 Circuit Type	PC Pressure Transducer	A Pressure Range	F* Type of Seal	A Type of Port	6 Termination Style	G Pressure Measurement
2 20PC Family	**2** Noncompensated low cost		**A** 1 psi **C** 15 psi **F** 100 psi	**E** EPDM **F** Fluorosilicone **N** Neoprene **S** Silicone	**A** Straight **B** Barbed **D** Modular **J** Needle	**2** 2 x 2 **6** 1 x 4 (.600″)	**G** Gage

24PC SERIES ORDER GUIDE

Catalog Listing	Pressure Range psi	Span, mV			Sensitivity mV/psi Typ.	Overpressure psi Max.
		Min.	Typ.	Max.		
24PCE Type	0.5	24	35	46	70	20
24PCA Type	1.0	30	45	60	45	20
24PCB Type	5.0	85	115	145	23	20
24PCC Type	15	165	225	285	15	45
24PCD Type	30	240	330	420	11	60
24PCF Type	100	156	225	294	2.25	200
24PCG Type	250	145	212	280	0.85	500

SENSOR SELECTION GUIDE

2 Product Family	4 Circuit Type	PC Pressure Transducer	A Pressure Range	F* Type of Seal	A Type of Port	2 Termination Style	G Pressure Measurement
2 20PC family	**4** Noncompensated		**A** 1 psi **B** 5 psi **C** 15 psi **D** 30 psi **E** 0.5 psi **F** 100 psi **G** 250 psi	**E** EPDM **F** Fluorosilicone **N** Neoprene **S** Silicone	**A** Straight **B** Barbed **C** Luer **D** Modular **H** M5 Thread **I** 90° Port **J** Needle **K** Reverse 90° **L** 1/4 - 28 UNF w/Cable Lock **M** 1/4 - 28 UNF w/o Cable Lock **S** Manifold	**1** 1 x 4 (.400″) **2** 2 x 2 **6** 1 x 4 (.600″)	**G** Gage **D** Differential

26PC SERIES ORDER GUIDE

Catalog Listing	Pressure Range psi	Span, mV			Sensitivity mV/psi Typ.	Overpressure psi Max.
		Min.	Typ.	Max.		
26PCA Type	1	14.7	16.7	18.7	16.7	20
26PCB Type	5.0	47	50	53	10	20
26PCC Type	15	97	100	103	6.67	45
26PCD Type	30	97	100	103	3.33	60
26PCF Type	100	95	100	105	1.00	200

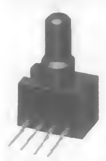
SENSOR SELECTION GUIDE

2 Product Family	6 Circuit Type	PC Pressure Transducer	B Pressure Range	F* Type of Seal	A Type of Port	2 Termination Style	G Pressure Measurement
2 20PC family	**6** Compensated Calibrated		**A** 1 psi **B** 5 psi **C** 15 psi **D** 30 psi **F** 100 psi **J** 38 psi **K** 38 psi (passivated**)	**E** EPDM **F** Fluorosilicone **N** Neoprene **S** Silicone	**A** Straight **B** Barbed **C** Luer **D** Modular **H** M5 Thread **I** 90° Port **J** Needle **K** Reverse 90° Port **L** 1/4 - 28 UNF w/Cable Lock **M** 1/4 - 28 UNF w/o Cable Lock **S** Manifold	**1** 1 x 4 (.400″) **2** 2 x 2 **6** 1 x 4 (.600″)	**G** Gage **D** Differential

*Other media seals available
**P2 side of die coated for environmental and dielectic protection

Pressure Sensors
Gage/Unamplified-Noncompensated

Basic Sensors



FEATURES
- Lowest priced pressure sensor
- Miniature package
- Can be used to measure with vacuum or positive pressure
- Operable after exposure to frozen conditions
- 2 mA constant current excitation significantly reduces sensitivity shift over temperature*

22PC SERIES PERFORMANCE CHARACTERISTICS at 10.0 ±0.01 VDC Excitation, 25°C

	Min.	Typ.	Max.	Units
Excitation	---	10	12	VDC
Null Shift, 25° to 0°, 25° to 50°C	---	±2.0	---	mV
Null Offset	−30	0	+30	mV
Linearity, P2 > P1, BFSL	---	±0.25	±1.0	% Span
Span Shift, 25° to 0°, 25° to 50°C	---	±6.0	---	% Span
Repeatability & Hysteresis	---	±0.15	---	% Span
Response Time	---	---	1.0	msec
Input Resistance	4.0 K	5.0 K	6.0 K	ohms
Output Resistance	4.0 K	5.0 K	6.0 K	ohms
Weight	---	2	---	grams

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40° to +85°C (−40° to +185°F)
Storage Temperature	−55° to +100°C (−67° to +212°F)
Shock	Qualification tested to 150 g
Vibration	Qualification tested to 0 to 2 kHz, 20 g sine
Media (P1 & P2)	Limited only to those media which will not attack polyetherimide, silicon, fluorosilicone, silicone, EPDM, and neoprene seals

22PC SERIES ORDER GUIDE

Catalog Listing	Pressure Range psi	Span, mV			Sensitivity mV/psi Typ.	Overpressure psi, Max.
		Min.	Typ.	Max.		
22PCA Type	1.0	25	42	59	42	20
22PCC Type	15	156	225	294	15	45
22PCF Type	100	147	225	303	2.3	200

SENSOR SELECTION GUIDE

2 Product Family	2 Circuit Type	PC Pressure Transducer	A Pressure Range	F Type of Seal	A Type of Port	6 Termination Style	G Pressure Measurement
2 20PC Family	**2** Noncompensated low cost		**A** 1 psi **C** 15 psi **F** 100 psi	**E** EPDM **F** Fluorosilicone **N** Neoprene **S** Silicone	**A** Straight **B** Barbed **D** Modular **J** Needle	**2** 2 x 2 **6** 1 x 4 (.600″)	**G** Gage

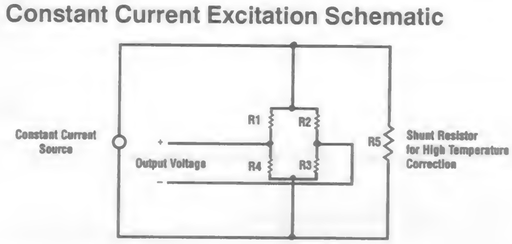
Example: 22PCAFA6G
Non-compensated low cost 1 psi sensor with fluorosilicone seal, straight port, 1 x 4 termination and gage pressure measurement.
See Accessory Guide, page 27.

Note: Not all catalog listings are established. Please refer to the Order Guides, or contact the MICRO SWITCH Application Center at the 800 number.

*Non-compensated pressure sensors, excited by constant current instead of voltage, exhibit temperature compensation of Span. Application Note #1 briefly discusses current excitation.

Constant current excitation has an additional benefit of temperature measurement. When driven by a constant current source, a silicon pressure sensor's terminal voltage will rise with increased temperature. The rise in voltage not only compensates the Span, but is also an indication of die temperature.

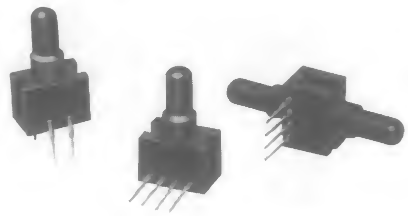
Constant Current Excitation Schematic



Pressure Sensors

Gage and Differential/Unamplified-Noncompensated

Basic Sensors



FEATURES

- Miniature package
- Variety of gage pressure port configurations - easily and quickly modified for your special needs
- Operable after exposure to frozen conditions
- Ideal for wet/wet differential applications
- Choice of termination for gage sensors
- 2 mA constant current excitation significantly reduces sensitivity shift over temperature*
- Can be used to measure vacuum or positive pressure

24PC SERIES PERFORMANCE CHARACTERISTICS at 10.0 ±0.01 VDC Excitation, 25°C

	Min.	Typ.	Max.	Units
Excitation	---	10	12	VDC
Null Offset	−30	0	+30	mV
Null Shift, 25° to 0°, 25° to 50°C	---	±2.0	---	mV
Linearity, P2 > P1, BFSL	---	±0.25	±1.0	%Span
Span Shift, 25° to 0°, 25° to 50°C	---	±5.0*	---	%Span
Repeatability & Hysteresis	---	±0.15	---	%Span
Response Time	---	---	1.0	msec
Input Resistance	4.0 K	5.0 K	6.0 K	ohms
Output Resistance	4.0 K	5.0 K	6.0 K	ohms
Stability over One Year	---	±0.5	---	%Span
Weight	---	2	---	grams

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40° to +85°C (−40° to +185°F)
Storage Temperature	−55° to +100°C (−67° to +212°F)
Shock	Qualification tested to 150 g
Vibration	Qualification tested to 0 to 2 kHz, 20 g sine
Media (P1 & P2)	Limited only to those media which will not attack polyetherimide, silicon, fluorosilicone, silicone, EPDM and neoprene seals.

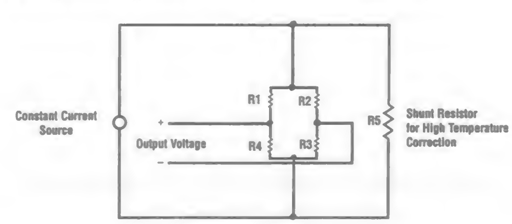
24PC SERIES ORDER GUIDE

Catalog Listing	Pressure Range psi	Span, mV			Sensitivity mV/psi Typ.	Overpressure psi Max.
		Min.	Typ.	Max.		
24PCE Type	0.5	24	35	46	70	20
24PCA Type	1.0	30	45	60	45	20
24PCB Type	5.0	85	115	145	23	20
24PCC Type	15	165	225	285	15	45
24PCD Type	30	240	330	420	11	60
24PCF Type	100	156	225	294	2.25	200
24PCG Type	250	145	212	280	0.85	500

*Non-compensated pressure sensors, excited by constant current instead of voltage, exhibit temperature compensation of Span. Application Note #1 briefly discusses current excitation.

Constant current excitation has an additional benefit of temperature measurement. When driven by a constant current source, a silicon pressure sensor's terminal voltage will rise with increased temperature. The rise in voltage not only compensates the Span, but is also an indication of die temperature.

Constant Current Excitation Schematic



Pressure Sensors
Gage and Differential/Unamplified-Noncompensated

SENSOR SELECTION GUIDE

2 Product Family	4 Circuit Type	PC Pressure Transducer	A Pressure Range	F* Type of Seal	A Type of Port	2 Termination Style	G Pressure Measurement
2 20PC family	**4** Noncom-pensated		**A** 1 psi **B** 5 psi **C** 15 psi **D** 30 psi **E** 0.5 psi **F** 100 psi **G** 250 psi	**E** EPDM **F** Fluorosilicone **N** Neoprene **S** Silicone	**A** Straight **B** Barbed **C** Luer **D** Modular **H** M5 Thread **I** 90° Port **J** Needle **K** Reverse 98 Port **L** 1/4 - 28 UNF w/Cable Lock **M** 1/4 - 28 UNF w/o Cable Lock **S** Manifold	**1** 1 x 4 (.400") **2** 2 x 2 **6** 1 x 4 (.600")	**G** Gage **D** Differential

Example: 24PCAFA2G
Standard, non-compensated 1 psi sensor with fluorosilicone seal, straight port, 2 x 2 terminals, and Gage pressure measurement.
*Other media seal materials may be available.

See Accessory Guide, page 27.

Not all combinations are established. Contact 800 number before final design.

Pressure Sensors

Absolute Unamplified Noncompensated

NEW

FEATURES

- Absolute pressure measurement
- Miniature package
- 2-15 and 2-30 psi pressure ranges
- 2 mA constant current excitation significantly reduces sensitivity shift over temperature*

24PC PERFORMANCE SPECIFICATIONS

Accuracy Specifications @ 10.0 ± .01 VDC Excitation, 25°C

Parameter	Range psia	bar	Min.	Typ.	Max.	Units
Excitation			—	10	12	VDC
Null Shift	2-15	1		±2.0	±4.0	mV
0 to 25°C, 25 to 50°C	2-30	2		±2.0	±5.5	
Linearity	2-15	1		.10	.20	% Span
B.F.S.L. P2 < P1**	2-30	2		.15	.30	
Sensitivity Shift 0 to 25°C, 25 to 50°C	All			±5.0	±6.5	% Span
Repeatability & Hysteresis	All			±0.5		% Span
Input Resistance			4.0 K	5.0 K	6.0 K	Ohms
Output Resistance			4.0 K	5.0 K	6.0 K	Ohms
Weight			—	2.0	—	grams

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40 to +85°C (−40 to +185°F)
Storage Temperature	−55 to +100°C (−67 to +212°F)
Shock	Qualification tested to 150 G
Vibration	Qualification tested to 0 to 2 kHz, 20 G sine
Media Compatibility	Limited only to those media which will not attack polyetherimide, silicon, fluorosilicone and silicone seals.

*Span: the algebraic difference between output end points
**B.F.S.L.: Best Fit Straight Line

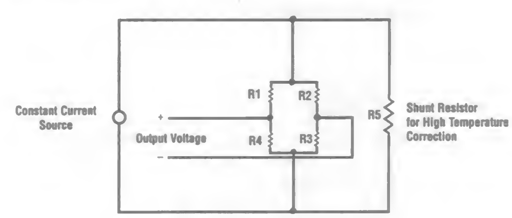
24PC ABSOLUTE ORDER GUIDE

Catalog Listing Type	Pressure Range psia	Span, mV			Null Offset mV			Sensitivity mV/psi Typ.	Over-pressure psia Typ.
		Min.	Typ.	Max.	Min.	Typ.	Max.		
24PCC	2-15	−140	−200	−260	−46	−16	+14	15	45
24PCD	2-30	−160	−300	−440	−61	−16	+29	11	60

*Non-compensated pressure sensors, excited by constant current instead of voltage, exhibit temperature compensation of Span. Application Note #1 briefly discusses current excitation.

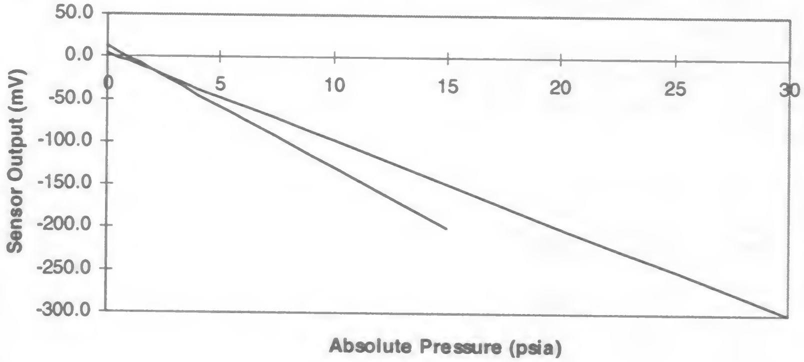
Constant current excitation has an additional benefit of temperature measurement. When driven by a constant current source, a silicon pressure sensor's terminal voltage will rise with increased temperature. The rise in voltage not only compensates the Span, but is also an indication of die temperature.

Constant Current Excitation Schematic

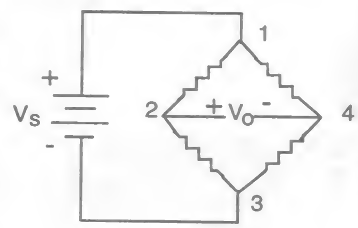


Pressure Sensors
Absolute Unamplified Noncompensated

24PC SERIES ABSOLUTE PRESSURE SENSOR OUTPUT CURVE



EXCITATION SCHEMATIC



TERMINATION STYLE

Style 6 - 1 x 4
Pin 1 = Vs (+)
Pin 2 = Output (+)
Pin 3 = Ground (–)
Pin 4 = Output (–)

Pin 1 is notched
Pin 2 is next to
Pin 1, etc.

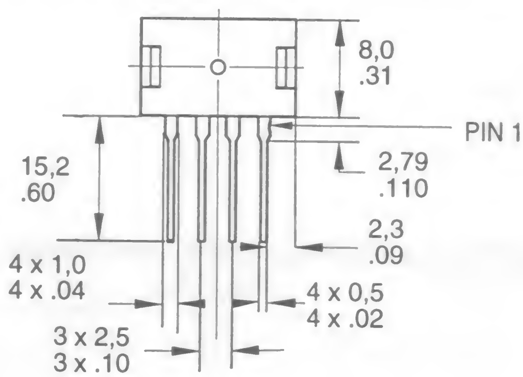
SENSOR SELECTION GUIDE

2 Product Family	4 Circuit Type	PC Pressure Transducer	C Pressure Range	F** Type of Seal	D* Type of Port (P1)	6 Termination Style	A Pressure Measurement
2 20PC Family	**4** Standard noncompensated		**C** 2-15 psia 1 bar **D** 2-30 psia 2 bar	**F** Fluoro-silicone	**A** Straight **D** Modular	**6** 1 x 4 (.600″ long)	**A** Absolute

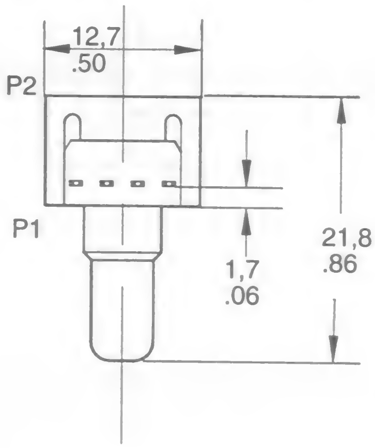
*Port type refers to P1
**Media seal is on P1 side and will not be in contact with media

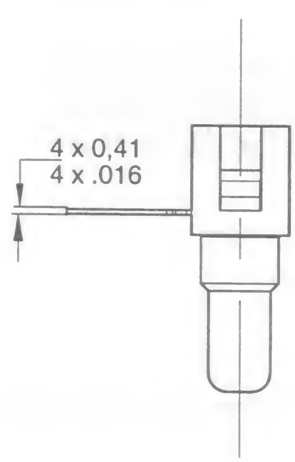
Example: 24PCCFD6A
Non-compensated 15 psi Absolute sensor with fluorosilicone seal, modular port, 1 x 4 terminals, .600″ long.
See Accessory Guide, page 27.

MOUNTING DIMENSIONS (for reference only)

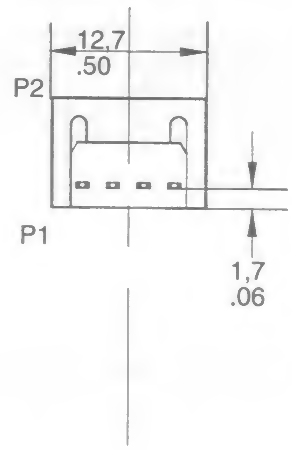


A Straight Port



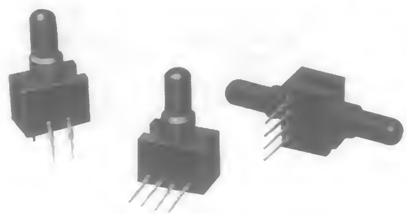


D Modular Port



Pressure Sensors
Gage and Differential/Unamplified-Compensated

Temperature Compensated Sensors



FEATURES
- Lowest priced sensor with temperature compensation and calibration
- Variety of gage pressure port configurations - easily and quickly modified for your special needs
- Operable after exposure to frozen conditions
- Choice of termination for gage sensors
- Calibrated Null and Span
- Temperature compensated for Span over 0 to 50°C
- Provides interchangeability
- Can be used to measure vacuum or positive pressure
- Ideal for wet/wet differential applications

26PC SERIES PERFORMANCE CHARACTERISTICS at 10.0 ±0.01 VDC Excitation, 25°C

	Min.	Typ.	Max.	Units
Excitation	---	10	16	VDC
Repeatability & Hysteresis	---	±0.20	---	%Span
Response Time	---	---	1.0	msec
Input Resistance	5.5 K	7.5 K	11.5 K	ohms
Output Resistance	1.5 K	2.5 K	3.0 K	ohms
Stability over One Year	---	±0.5	---	%Span
Weight	---	2	---	grams

Total error calculation, see page 105.

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40° to 85°C (−40° to +185°F)
Storage Temperature	−55° to +100°C (−67° to +212°F)
Compensated Temperature	0° to +50°C (32° to +122°F)
Shock	Qualification tested to 150 g
Vibration	MIL-STD-202. Method 213 (150g halfsine, 11 msec)
Media (P1 & P2)	Limited only to those media which will not attack polyetherimide, silicon, fluorosilicone, silicone, EPDM, and neoprene seals.

26PC SERIES ORDER GUIDE

Catalog Listing	Pressure Range (psi)	Linearity (% span)		Null Shift (mV)		Null Offset (mV)			Span Shift (% span)		Span (mV)			Sensitivity mV/psi	Over-pressure psi
		Typ.	Max	Typ.	Max	Min.	Typ.	Max.	Typ.	Max.	Min.	Typ.	Max.	Typ.	Max.
26PCA TYPE	1	0.25	0.5	±0.5	±1.0	−1.5	0	+1.5	±1.0	±2.0	14.7	16.7	18.7	16.7	20
26PCB TYPE	5	0.4	0.5	±0.5	±1.0	−1.5	0	+1.5	±1.0	±1.5	47	50	53	10.0	20
26PCC TYPE	15	0.25	0.5	±0.5	±1.0	−1.5	0	+1.5	±0.75	±1.5	97	100	103	6.67	45
26PCD TYPE	30	0.1	0.2	±0.75	±1.5	−1.5	0	+1.5	±0.75	±1.5	97	100	103	3.33	60
26PCF TYPE	100	0.1	0.2	±1.0	±2.0	−2.0	0	+2.0	±0.5	±1.5	95	100	105	1.0	200
26PCJ TYPE	38*	0.1	0.5	±0.7	±1.5	−1.5	0	+1.5	±1.0	±1.5	37.5	39.5	41.5	2.63	60
26PCK TYPE	38*	0.1	0.5	±0.7	±1.5	−1.5	0	+1.5	±1.0	±1.5	37.5	39.5	41.5	2.63	60

*Accuracy specifications calculated at 15 psi.

Pressure Sensors
Gage and Differential/Unamplified-Compensated

SENSOR SELECTION GUIDE

2 **Product Family**	6 **Circuit Type**	PC **Pressure Transducer**	B **Pressure Range**	F* **Type of Seal**	A **Type of Port**	2 **Termination Style**	G **Pressure Measurement**
2 20PC family	**6** Compensated Calibrated		**A** 1 psi **B** 5 psi **C** 15 psi **D** 30 psi **F** 100 psi **J** 38 psi **K** 38 psi (passivated**)	**E** EPDM **F** Fluorosilicone **N** Neoprene **S** Silicone	**A** Straight **B** Barbed **C** Luer **D** Modular **H** M5 Thread **I** 90° Port **J** Needle **K** Reverse 90° Port **L** 1/4-28 UNF w/Cable Lock **M** 1/4 - 28 UNF w/o Cable Lock **S** Manifold	**1** 1 x 4 (.400″) **2** 2 x 2 **6** 1 x 4 (.600″)	**G** Gage **D** Differential

Example: 26PCBFA2G
Compensated and calibrated 5 psi sensor with fluorosilicone seal, straight port, 2 x 2 terminals, and Gage pressure measurement.
*Other media seal materials may be available.
**P2 side of die coated for environmental and dielectic protection.

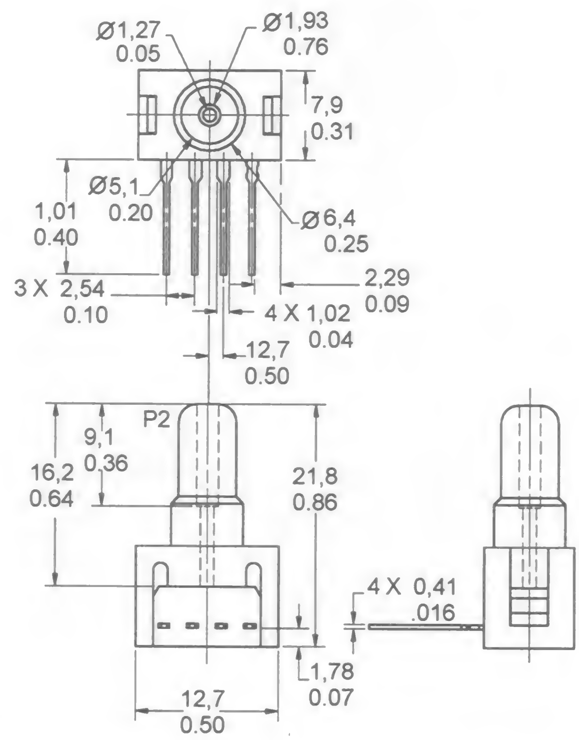
See Accessories Guide, page 27.

Not all combinations are established. Contact 800 number before final design.

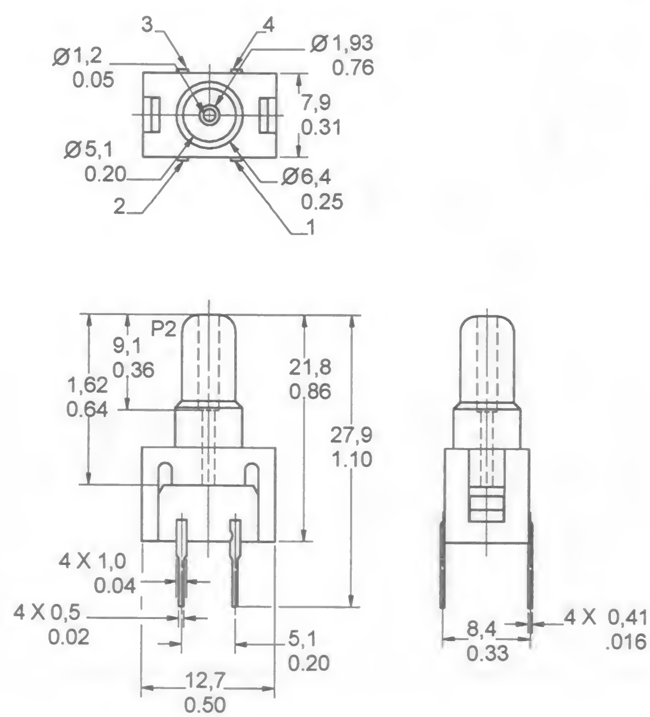
Pressure Sensors
Gage and Differential/Unamplified

GAGE SENSOR
Pressure is applied to port P2. Port P1 vents to ambient pressure

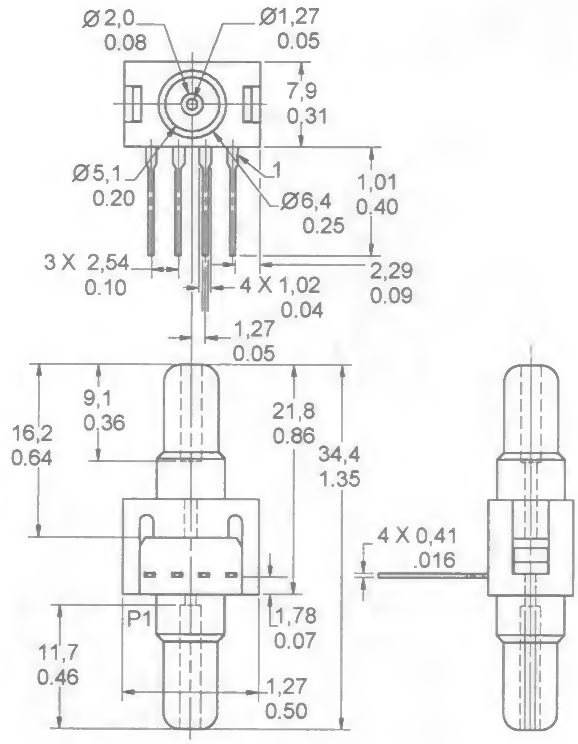
Mounting Dimensions (for reference only)
1 x 4 Termination (Style 1), Straight Port (Style A)
Pin 1 is notched, and is shown at the right of the package. Pin 2 is next to Pin 1, etc.



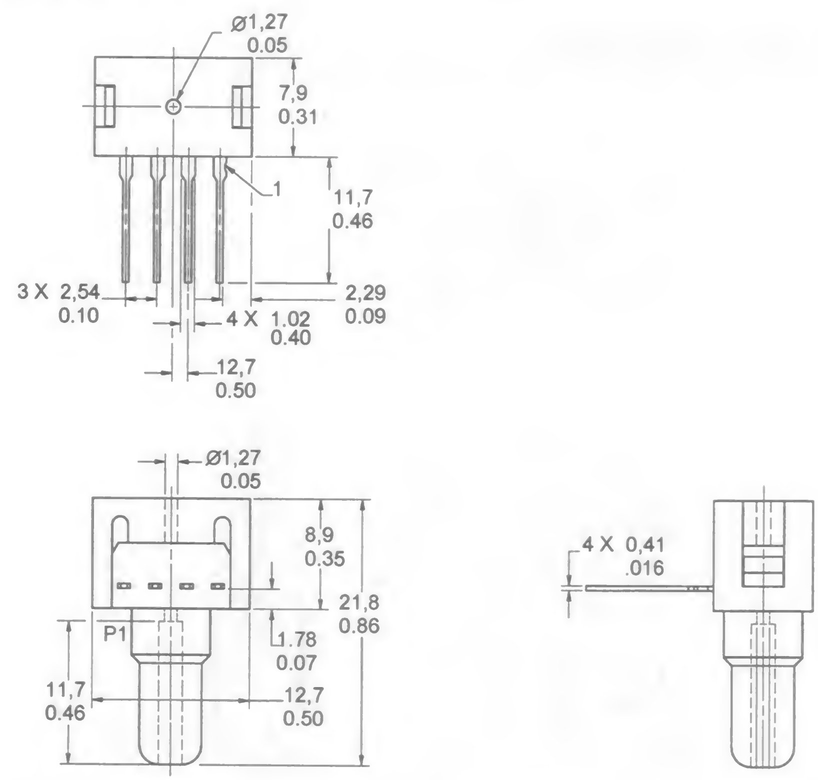
2 x 2 Termination (Style 2), Straight Port (Style A)
Pin 1 is notched and is shown at lower right corner. Pins 2, 3, and 4 are clockwise.



Straight Port, 1 x 4 Termination (Style 1) ONLY
Port 1 is near terminals

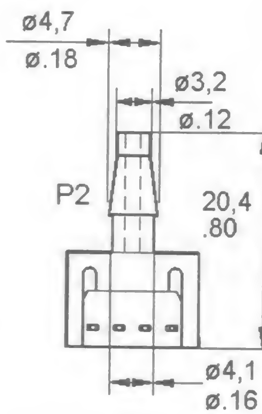


Absolute Sensor
1 x 4 Termination (Style 1), Port 1 is near terminals

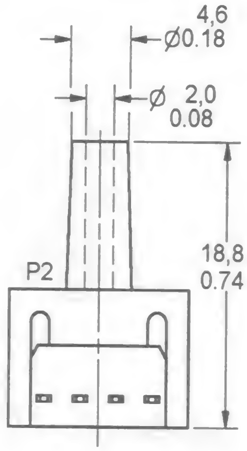


OTHER GAGE SENSOR PORT STYLES
(2 x 2 or 1 x 4 Termination)

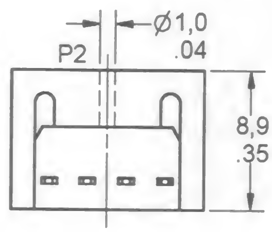
B Barbed



C Luer



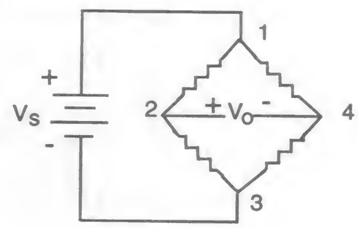
D Modular



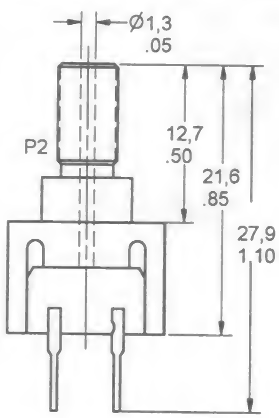
20PC SERIES CIRCUIT - NOTES
1. Circled numbers refer to Sensor Terminals (interface pins).
2. V_O increases with pressure change.
3. $V_O = V_2 - V_4$
4. Pin 1 designated with a notch.

Pin Designation
Pin 1 = V_S (+)
Pin 2 = Output (+)
Pin 3 = Ground (–)
Pin 4 = Output (–)

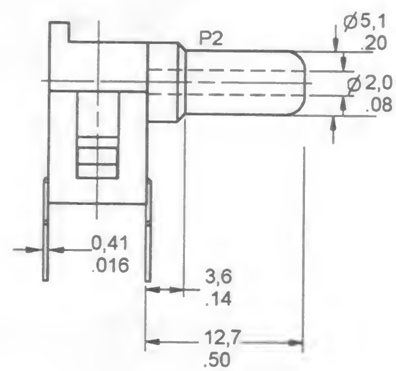
EXCITATION



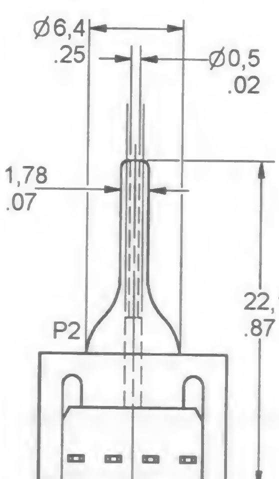
H M5 Thread
O-Ring Size 007 O-Ring Counterbore
1,02 mm (.040) deep ±0,13 (.005) x 7,6 mm (.30) ±0,8 (.003)



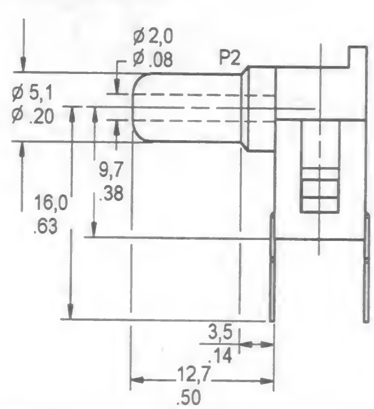
I 90°



J Needle

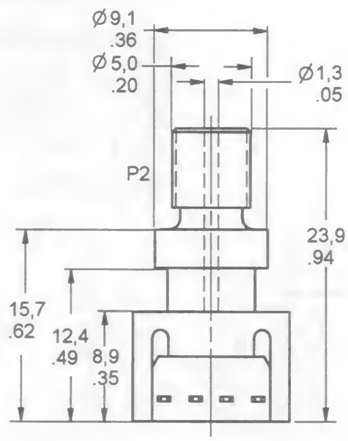


K Reverse 90°

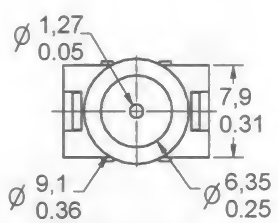


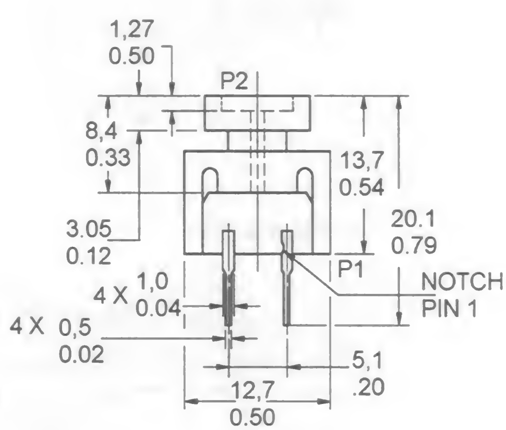
OTHER GAGE SENSOR PORT STYLES
(2 x 2 or 1 x 4 Termination)

M 1/4-28 UNF Thread
O-Ring Size 009 O-Ring Counterbore
1,02 mm (.040) deep ±0,05 (.002) x 9,1 mm (.360) ±0,8 (.003)

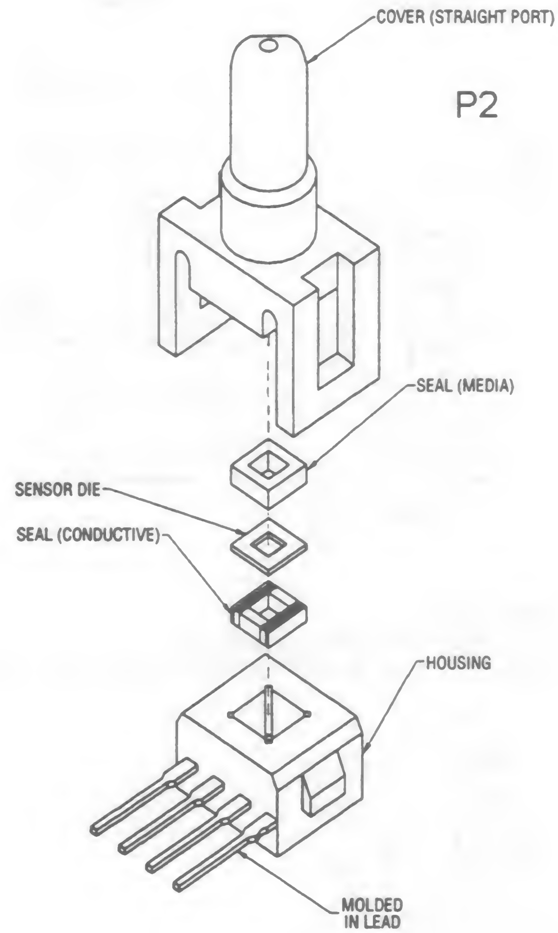


S Manifold





20PC Construction



Pressure Sensors

Gage Unamplified Noncompensated Flow-Through

FEATURES

- Measures positive and negative gage pressures
- Flow-through port design fits in-line with application
- Popular port sizes:
  - 8 mm (.315 in.) OD (1/4 in. ID tubing or standard connectors)
  - 0.144 in. OD (1/8 in. ID tubing)
- Medical grade ISO 10993-1 (USP Class 6) port material
- Silicon sensor chip
- 24 inch wire harness with splash proof connector
- Minimal deadspace — efficient cleansing and disinfecting

Unamplified

24PC SERIES PERFORMANCE CHARACTERISTICS at 10.0 ±0.01 VDC EXCITATION, 25°C

	Min.	Typ.	Max.	Units
Excitation	---	10	12	VDC
Null Shift, 25° to 0°, 25° to 50°C	---	±2.0	---	mV
Null Offset	−30	0	+30	mV
Linearity, P2 > P1, BFSL	---	±0.5	---	%Span
Span Shift, 25° to 0°, 25° to 50°C	---	±5.0	---	%Span
Repeatability & Hysteresis	---	±0.2	---	%Span
Response Time	---	---	1.0	msec
Input Resistance	4.0 K	5.0 K	6.0 K	ohms
Output Resistance	4.0 K	5.0 K	6.0 K	ohms
Stability over One Year	---	±0.5	---	%Span

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40° to +85°C (−40° to +185°F)
Storage Temperature	−55° to +100°C (−67° to +212°F)
Shock	Qualification tested to 150 g
Vibration	Qualification tested to 0 to 2 kHz, 20 g sine
Media Compatibility	Limited only to those media which will not attack polysulfone, silicon, fluorosilicone, silicone, EPDM, and neoprene seals

24PC SERIES FLOW THROUGH ORDER GUIDE

Catalog Listing	Pressure Range psi	Span, mV			Sensitivity mV/psi Typ.	Overpressure psi Max.
		Min.	Typ.	Max.		
24PCE Type	0.5	25	35	45	70	20
24PCA Type	1.0	30	45	60	45	20
24PCB Type	5.0	85	115	145	23	20
24PCC Type	15	165	225	285	15	45
24PCD Type	30	240	330	420	11	60
24PCF Type	100	156	225	294	2.25	200
24PCG Type	250	145	212	280	0.85	500

Pressure Sensors
Gage Unamplified Noncompensated Flow-Through

SENSOR SELECTION GUIDE

2 Product Family	4 Circuit Type	PC Pressure Transducer	A Pressure Range	F* Type of Seal	N Port Type	5 Termination Style	G Pressure Measurement
2 20PC Family	**4** Noncom-pensated		**A** 1 psi **B** 5 psi **C** 15 psi **D** 30 psi **E** 0.5 psi **F** 100 psi **G** 250 psi	**E** EPDM **F** Fluorosilicone **N** Neoprene **S** Silicone	**G** Small **N** Large (.350 dia.) **P** Large (.315 dia.)	**2** 4-pin DIP **5** Wire harness **6** 4-pin SIP	**G** Gage

Example: 24PCBFG5G
Non-compensated 5 psi sensor, fluorosilicone seal, small flow-through ports, wire harness, and gage pressure measurement.
*Other media seal materials may be available.

Note: Not all combinations are established. Contact 800 number before final design.

See Accessory Guide, page 27.

Pressure Sensors
Gage Unamplified Compensated Flow-Through

FEATURES
- Measure positive and negative gage pressures
- Flow-through port design fits in-line with application
- Popular port sizes:
  - 8 mm (.315 in.) OD (1/4 in. ID tubing or standard connectors)
  - 0.144 in. OD (1/8 in. ID tubing)
- Medical grade ISO 10993-1 (USP Class 6) port material
- Silicon sensor chip
- 24 inch wire harness with splash proof connector
- Minimal deadspace — efficient cleansing and disinfecting

26PC SERIES PERFORMANCE CHARACTERISTICS at 10.0 ±0.01 VDC Excitation, 25°C

	Min.	Typ.	Max.	Units
Excitation	---	10	16	VDC
Repeatability & Hysteresis	---	±0.20	---	% Span
Response Time	---	---	1.0	msec
Input Resistance	5.5 K	7.5 K	11.5 K	ohms
Output Resistance	1.5 K	2.5 K	3.0 K	ohms
Stability over One Year	---	±0.5	---	% Span
Weight	---	2	---	grams

Total error calculation, see page 105.

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40° to 85°C (−40° to +185°F)
Storage Temperature	−55° to +100°C (−67° to +212°F)
Compensated Temperature	0° to +50°C (32° to +122°F)
Shock	Qualification tested to 150 g
Vibration	MIL-STD-202. Method 213 (150g halfsine, 11 msec)
Media (P1 & P2)	Limited only to those media which will not attack polyetherimide, silicon, fluorosilicone, silicone, EPDM, and neoprene seals.

26PC SERIES ORDER GUIDE

Catalog Listing	Pressure Range (psi)	Linearity (% span)		Null Shift (mV)		Null Offset (mV)			Span Shift (% span)		Span (mV)			Sensitivity mV/psi	Over-pressure psi
		Typ.	Max	Typ.	Max	Min.	Typ.	Max.	Typ.	Max.	Min.	Typ.	Max.	Typ.	Max.
26PCA TYPE	1	0.25	0.5	±0.5	±1.0	−1.5	0	+1.5	±1.0	±2.0	14.7	16.7	18.7	16.7	20
26PCB TYPE	5	0.4	0.5	±0.5	±1.0	−1.5	0	+1.5	±1.0	±1.5	47	50	53	10.0	20
26PCC TYPE	15	0.25	0.5	±0.5	±1.0	−1.5	0	+1.5	±0.75	±1.5	97	100	103	6.67	45
26PCD TYPE	30	0.1	0.2	±0.75	±1.5	−1.5	0	+1.5	±0.75	±1.5	97	100	103	3.33	60
26PCF TYPE	100	0.1	0.2	±1.0	±2.0	−2.0	0	+2.0	±0.5	±1.5	95	100	105	1.0	200
26PCJ TYPE	38*	0.1	0.5	±0.7	±1.5	−1.5	0	+1.5	±1.0	±1.5	37.5	39.5	41.5	2.63	60
26PCK TYPE	38*	0.1	0.5	±0.7	±1.5	−1.5	0	+1.5	±1.0	±1.5	37.5	39.5	41.5	2.63	60

*Accuracy specifications calculated at 15 psi.

Pressure Sensors
Gage Unamplified Compensated Flow-Through

SENSOR SELECTION GUIDE

2 Product Family	6 Circuit Type	PC Pressure Transducer	A Pressure Range	F* Type of Seal	N Port Type	5 Termination Style	G Pressure Measurement
2 20PC Family	**6** Compen-sated, Calibrated		**A** 1 psi **B** 5 psi **C** 15 psi **D** 30 psi **F** 100 psi **J** 38 psi **K** 38 psi (passivated)	**E** EPDM **F** Fluoro-silicone **N** Neoprene **S** Silicone	**G** Small **N** Large (.350 dia.) **P** Large (.315 dia.)	**2** 4-pin DIP **5** Wire harness **6** 4-pin SIP	**G** Gage

Example: 26PCBFG5G
Compensated, calibrated 5 psi sensor, fluorosilicone seal, small flow-through ports, wire harness, and gage pressure measurements.
*Other media seal materials may be available.

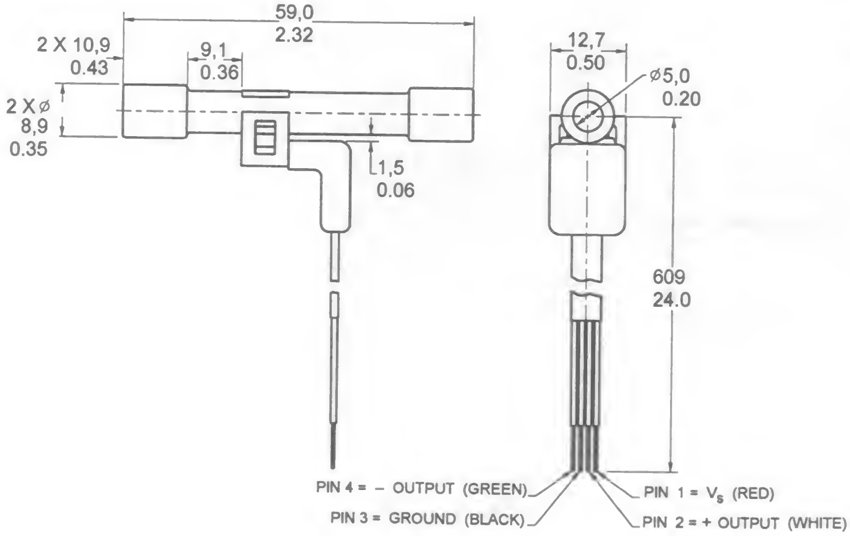
Note: Not all combinations are established. Contact 800 number before final design.

See Accessory Guide, page 27.

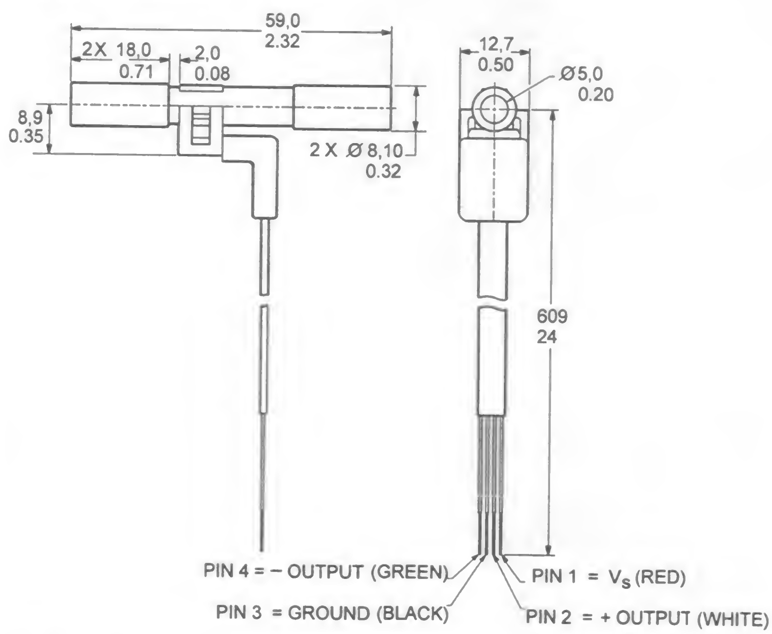
Pressure Sensors
Gage Unamplified Flow-Through

MOUNTING DIMENSIONS (for reference only)

Large Port Sensor N



Large Port Sensor P

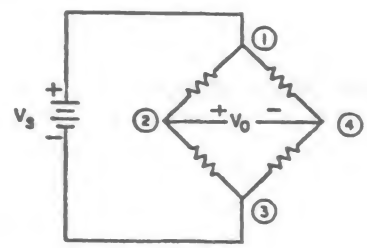


NOTE: Wire harness (PC-15175) may be purchased separately.

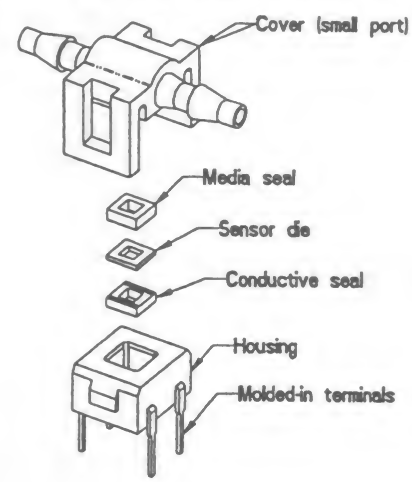
20PC CIRCUIT NOTES
1. Circled numbers refer to Sensor Terminals (interface pins).
2. V_0 increases with pressure change.
3. $V_0 = V_2 - V_4$

PIN DESIGNATION
Pin 1 = V_s (Red)
Pin 2 = Output, + (White)
Pin 3 = Ground, – (Black)
Pin 4 = Output, – (Green)

EXCITATION

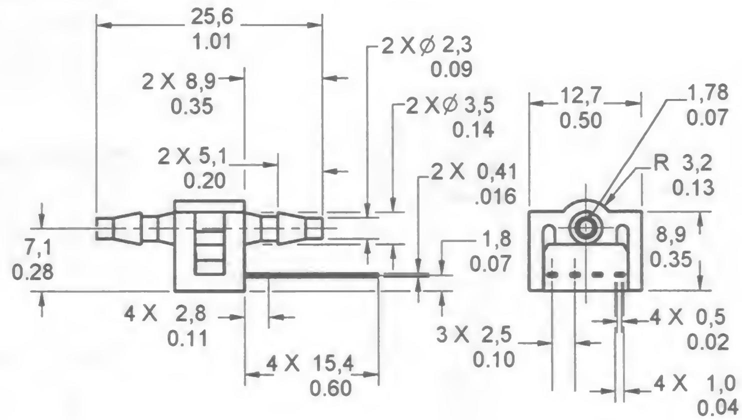


Flow-Through Construction

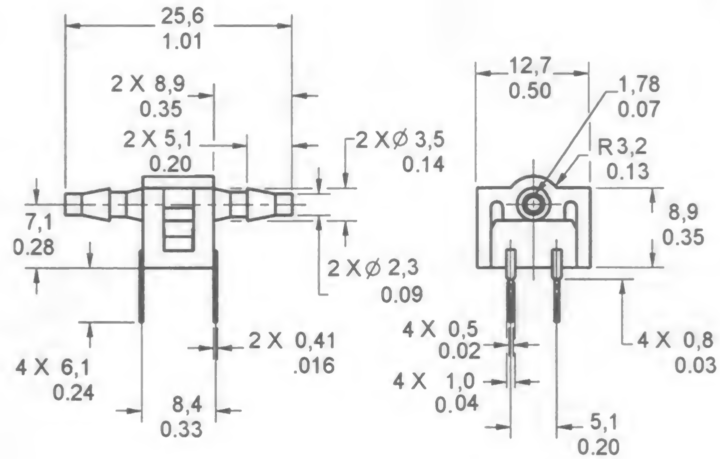


MOUNTING DIMENSIONS (for reference only)

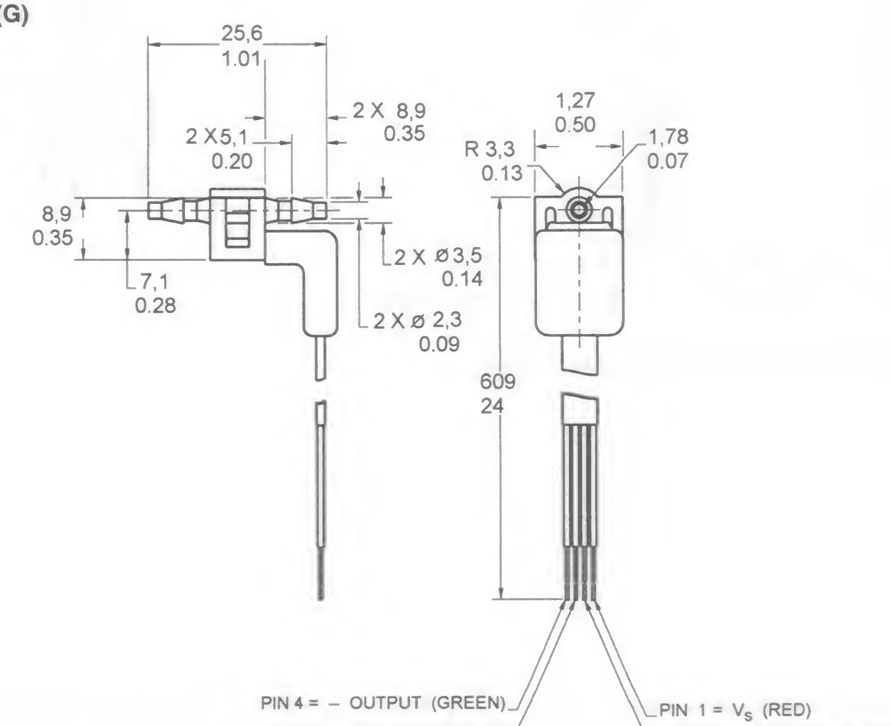
Small Port Sensor (1 x 4)



Small Port Sensor (2 x 2)



Small Port Sensor (G)



ACCESSORIES SELECTION GUIDE

Catalog Listing	Description	Drawing
PC-10182	Steel lockring (included with Port Style A, 1 x 4 terminals only) 22, 24, 26PC only	Figure 1
PC-15111	Cable retaining clip for large port Flow-Through sensor only	Figure 4
PC-15110	Single hole plastic bracket	Figure 3
PC-15015	Mounting bracket	Figure 6
PC-15132	Plastic Mounting bracket	Figure 5
20PCWHRC	Flow-Through wire harness and retaining clip	Figure 2
26PCBKT	Mounting bracket for large port Flow-Through sensor only	Figure 7
PC-15202	Mounting bracket for Luer Port	Figure 8
PC-15204	Mounting bracket for Straight Port	Figure 9

Figure 1 PC-10182
Steel Lockring

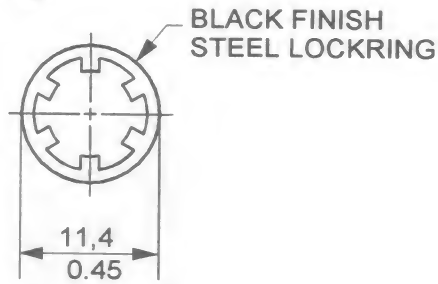


Figure 2 20PCWHRC
Wire Harness and Retaining Clip

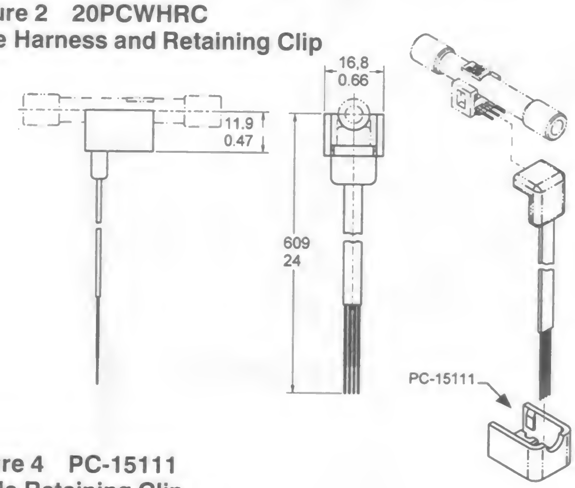


Figure 3 PC-15110
Single Hole Plastic Bracket

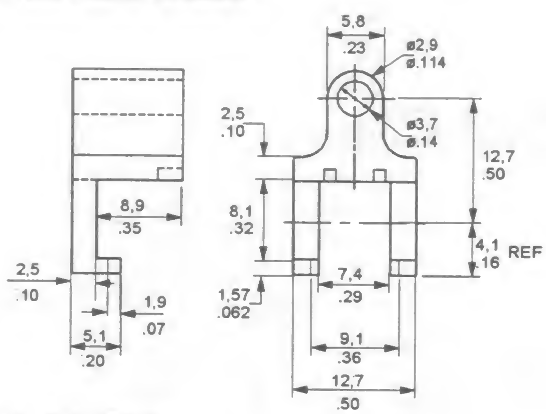


Figure 4 PC-15111
Cable Retaining Clip

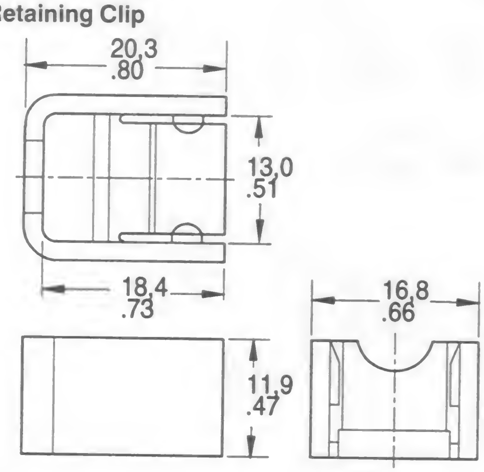


Figure 5 PC-15132
Plastic Mounting Bracket

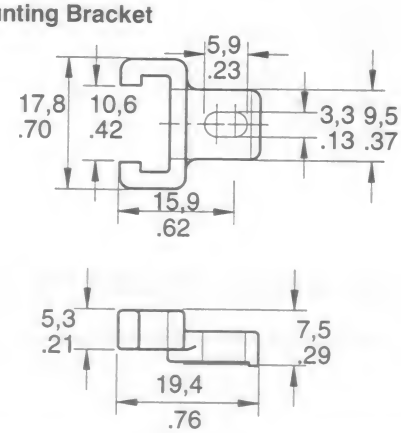


Figure 6 PC-15015
Mounting Bracket

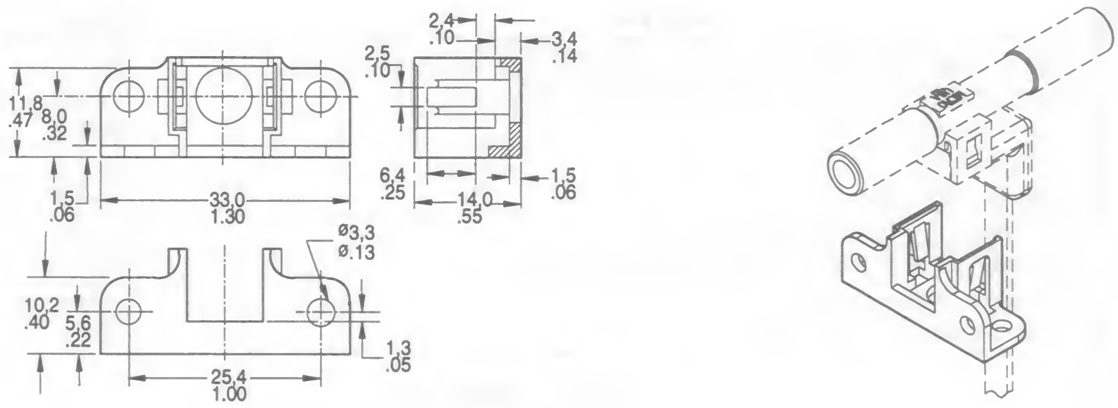


Figure 7 26PCBKT
For use with N, P Large Ports

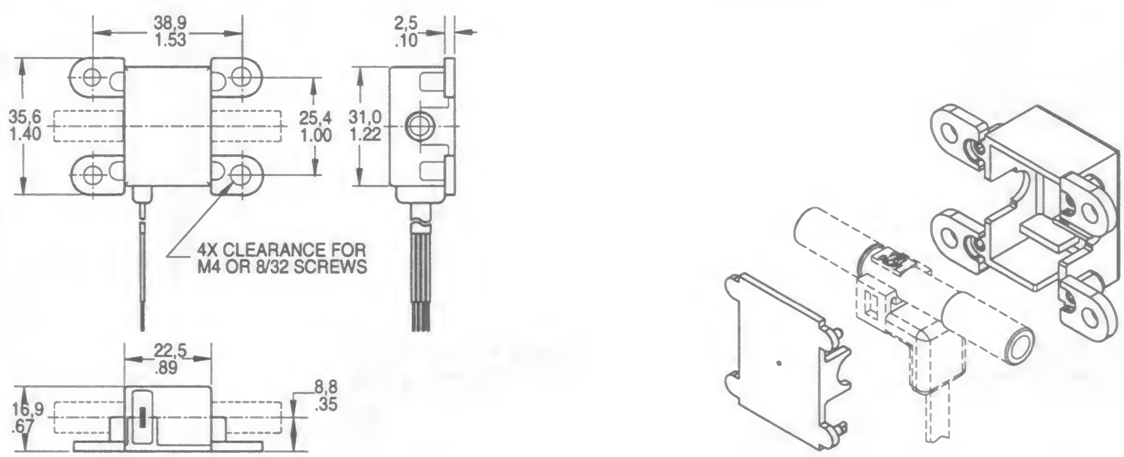


Figure 8 PC-15202
For use with C Luer Port

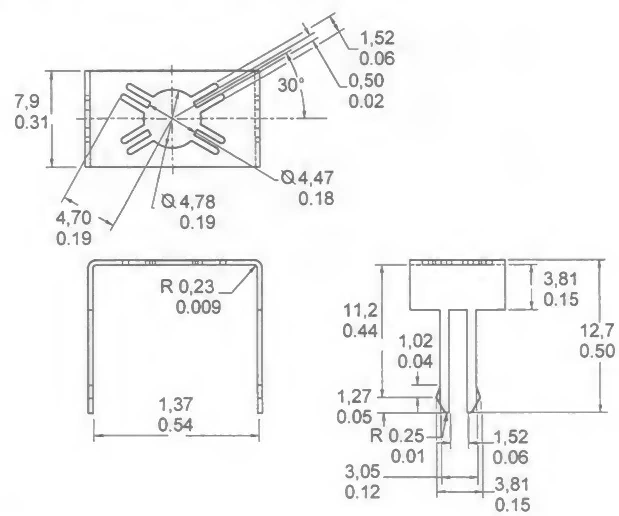
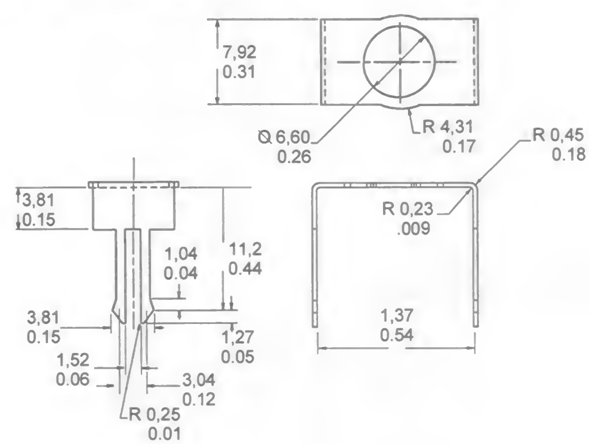


Figure 9 PC-15204
For use with A Straight Port



Note: PC-15202 and PC-15204 are Printed Circuit Board mountable and solderable; designed to be used in a .063 thick PC Board with a recommended mounting hole size of .125 ±.005 in.

Pressure Sensors

Low Pressure Gage & Differential/Unamplified

Temperature Compensated Sensors

FEATURES
- Miniature package
- Low pressure measurement
- Calibrated Null and Span
- Temperature compensated for Span over 0 to 50°C
- Provides interchangeability

176PC SERIES PERFORMANCE CHARACTERISTICS at 10.0 ±0.01 VDC Excitation, 25°C

	Min.	Typ.	Max.	Units
Excitation	---	10	16	VDC
Null Offset	−2	0	+2	mV
Null Shift, 25° to 0°, 25° to 50°C	---	±3.0	---	mV
Sensitivity Shift, 25° to 0°, 25° to 50°C	---	---	±4.0[1]	%Span
	---	---	±3.5[2]	%Span
Repeatability & Hysteresis	---	±0.25	---	%Span
Response Time	---	---	1.0	msec
Input Resistance	---	6.3 K	---	ohms
Output Resistance	---	4.0 K	---	ohms
Stability over One Year	---	±0.5	---	%Span
Weight	---	7	---	grams

Key: 1 = 0-7″, 0-14″ H_2O only
2 = 0-28″ H_2O only

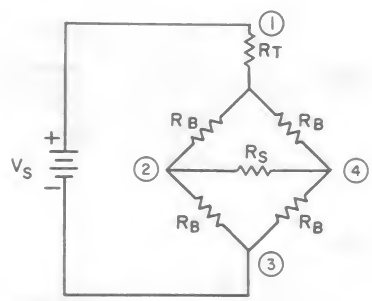
ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40° to +85°C (−40° to +185°F)	
Storage Temperature	−55° to +125°C (−67° to +257°F)	
Compensated Temperature	0° to +50°C (32° to +122°F)	
Shock	MIL-STD-202, Method 213 (150 g, half sine, 11 msec)	
Vibration	MIL-STD-202, Method 204 (10 to 2000 Hz at 20 g)	
Media	P2 port	Wetted materials; polyester housing, epoxy adhesive, silicon, borosilicate glass, and silicon-to-glass bond*
	P1 port	Dry gases only

* Liquid media containing some highly ionic solutions could potentially neutralize the chip-to-glass tube bond.

ELECTRICAL CONNECTIONS

(Internal Circuitry Shown)



NOTES
1. Circled numbers refer to sensor termination.
2. $V_0 = V_2 - V_4$ (referenced to pin 3).
3. R_B = Strain gage resistors (~4.8 kΩ).
4. R_T = Sensitivity temperature compensation resistor.
5. R_S = Sensitivity calibration resistor.

When a positive pressure is applied to port P2, the differential voltage $V_2 - V_4$ (voltage at pin 2, with respect to ground, increases and voltage at pin 4 decreases) increases linearly with respect to the input pressure. When a vacuum pressure is pulled at port P2 (or positive pressure applied to port P1) the voltage $V_2 - V_4$ decreases linearly with respect to the input pressure.

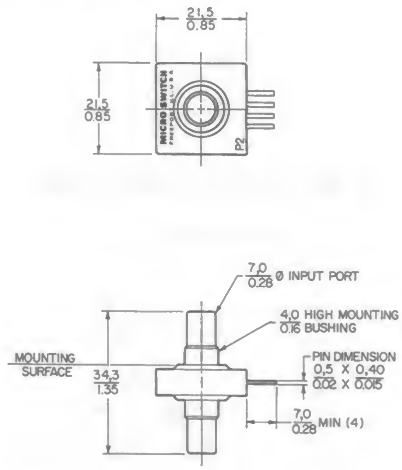
176PC SERIES ORDER GUIDE

Catalog Listing	Pressure Range H_2O	Span, mV			Sensitivity mV/″H_2O Typ.	Overpressure ″H_2O Max.	Linearity, %Span	
		Min.	Typ.	Max.			P2 > P1 Max.	P2 < P1 Max.
176PC07HG2	0-7	26	28	30	4.00	140	±3.00	±1.50
176PC07HD2	0-7	26	28	30	4.00	140	±3.00	±1.50
176PC14HG2	0-14	33	35	37	2.50	140	±3.00	±1.50
176PC14HD2	0-14	33	35	37	2.50	140	±3.00	±1.50

Pressure Sensors
Low Pressure Gage & Differential/Unamplified

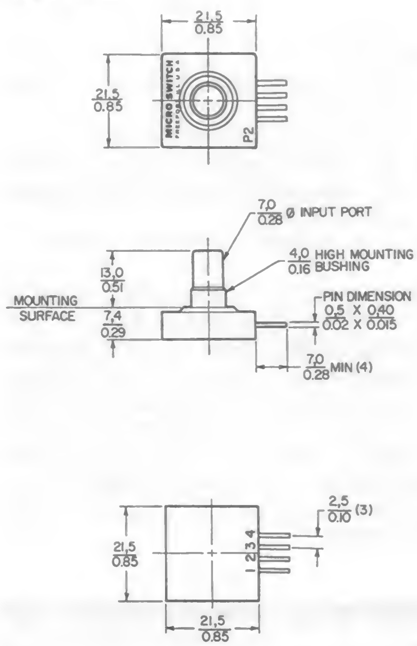
MOUNTING DIMENSIONS (For reference only)

Differential Types

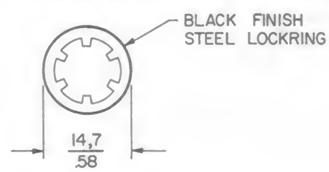


Terminals
1 – Vs (+)
2 – Output A
3 – Ground (–)
4 – Output B

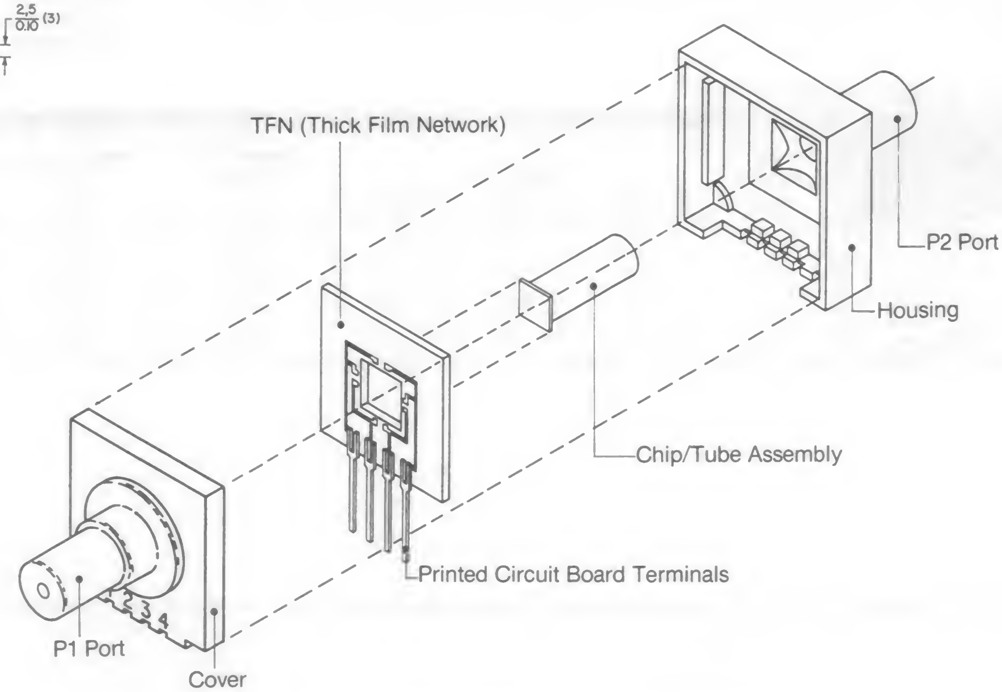
Gage Types



Mounting Hardware - PC10198



170PC CONSTRUCTION



Pressure Sensors
Miniature Signal Conditioned

40PC Series

NEW

FEATURES
- Smallest amplified sensor package
- Minimal PCB space
- Fully signal conditioned
- Operating temperature range from −45° to +125°C
- Silicon piezoresistive technology
- Monolithic design
- 6 Pin DIP package
- Port designed for O-ring interface
- Excellent media compatibility
- Accuracy of 0.2%

PERFORMANCE CHARACTERISTICS

Pressure Range	±50 mm Hg	0-15 psi	0-100 psi	0-150 psi	0-250 psi
Overpressure, max.	±170 mm Hg	45 psi	200 psi	300 psi	500 psi
Supply Voltage	5 VDC ±0.25				
Supply Current	10 mA max.				
Output Source Current	0.5 mA max.				
Output Sink Current	1.0 mA max.				
Operating Temperature	−45° to +125°C (−49° to +257°F)				
Storage Temperature	−55° to +125°C (−67° to +257°F)				
Hysteresis & Repeatability	0.15% Span, Typ.				
Ratiometricity (at 4.75 to 5.25 Supply Voltage)	±0.25% Span, Typ.				
Output Load Capacitance	0.05 microtarads, max.				
Full Scale					
−50 mm Hg	0.50 VDC Typ.				
+50 mm Hg	4.50 VDC Typ.				
All other pressure ranges	4.50 VDC Typ.				
Media Compatibility — P1 port	DRY GASES ONLY: Media must be compatible with epoxy based adhesive				
P2 port	Media must be compatible with glass, silicon, stainless steel, invar, Sn/Ni plating or Sn/Ag solder				

CAUTION
ELECTROSTATIC SENSITIVE DEVICES
DO NOT OPEN OR HANDLE EXCEPT AT A STATIC FREE WORKSTATION

ESD SENSITIVITY: CLASS I

Amplified

40PC SERIES ORDER GUIDE

Catalog Listing	Pressure Range psi	Pressure Type	Lead Style
40PC001B1A	±50 mm Hg	Bi-directional	1-unformed
40PC001B2A	±50 mm Hg	Bi-directional	2-formed away from port
40PC001B3A	±50 mm Hg	Bi-directional	3-formed towards port
40PC015G1A	0-15	Gage	1-unformed
40PC015G2A	0-15	Gage	2-formed away from port
40PC015G3A	0-15	Gage	3-formed towards port
40PC100G1A	0-100	Gage	1-unformed
40PC100G2A	0-100	Gage	2-formed away from port
40PC100G3A	0-100	Gage	3-formed towards port
40PC150G1A	0-150	Gage	1-unformed
40PC150G2A	0-150	Gage	2-formed away from port
40PC150G3A	0-150	Gage	3-formed towards port
40PC250G1A	0-250	Gage	1-unformed
40PC250G2A	0-250	Gage	2-formed away from port
40PC250G3A	0-250	Gage	3-formed towards port

Note: For tubing and O-Ring interface recommendations, see the 40PC Application Note in the Reference Section.

OUTPUT PERFORMANCE CHARACTERISTICS @ 25°C, 5VDC (unless otherwise noted)

Pressure Range	Null (VDC)	Span (VDC)	Sensitivity, Typ.	Linearity, B.F.S.L. (% Span) Max.		Null Shift (% Span) Max.	Span Shift (% Span) Max.	Combined Null and Span Shift (% Span) Max.
±50 mm Hg	2.50 ± 0.050	4.00 Typ.	40.0 mV/mm Hg	0.80	+25° to +50°C	±1.50	±1.50	—
					+25° to 0°C	±1.50	±1.50	—
0 to 15 psi	0.50 ± 0.11	4.00 ± 0.11	266.6 mV/psi	0.20	+25° to −18°C	±2.00	±0.75	±2.00
					+25° to +63°C	±2.00	±0.75	±2.00
					+25° to −45°C	±2.75	±1.00	±3.00
					+25° to +85°C	±2.75	±1.00	±3.00
					+25° to +125°C	—	—	—
0 to 100 psi	0.50 ± 0.04	4.00 ± 0.09	40.0 mV/psi	0.10	+25° to −18°C	±1.25	±0.75	±1.50
					+25° to +63°C	±1.25	±0.75	±1.50
					+25° to −45°C	±2.00	±1.00	±2.50
					+25° to +85°C	±2.00	±1.00	±2.50
					+25° to +125°C	±3.00	±2.00	±3.00
0 to 150 psi	0.50 ± 0.04	4.00 ± 0.07	26.6 mV/psi	0.10	+25° to −18°C	±0.75	±0.75	±0.75
					+25° to +63°C	±0.75	±0.75	±0.75
					+25° to −45°C	±1.00	±1.00	±1.00
					+25° to +85°C	±1.00	±1.00	±1.00
					+25° to +125°C	±1.50	±1.50	±1.50
0 to 250 psi	0.50 ± 0.04	4.00 ± 0.07	16.0 mV/psi	0.10	+25° to −18°C	±0.75	±0.75	±0.75
					+25° to +63°C	±0.75	±0.75	±0.75
					+25° to −45°C	±1.00	±1.00	±1.00
					+25° to +85°C	±1.00	±1.00	±1.00
					+25° to +125°C	±2.00	±2.00	±3.00

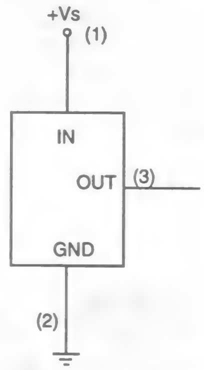
PERFORMANCE SPECIFICATIONS, TEMPERATURE/ACCURACY

Temperature Range	Total Accuracy (% Span) Max.			
	0 to 15 psi	**0 to 100 psi**	**0 to 150 psi**	**0 to 250 psi**
25°C	±0.4 (RSS)	±0.2 (RSS)	±0.2 (RSS)	±0.2 (RSS)
−18° to +63°C	±4.0	±2.5	±2.0	±2.0
−45° to +85°C	±4.0	±2.5	±2.0	±2.0
−45° to +125°C		±3.0	±2.5	±3.0

Note 1: Accuracy at 25°C is defined as RSS error for linearity, hysteresis, and repeatability.

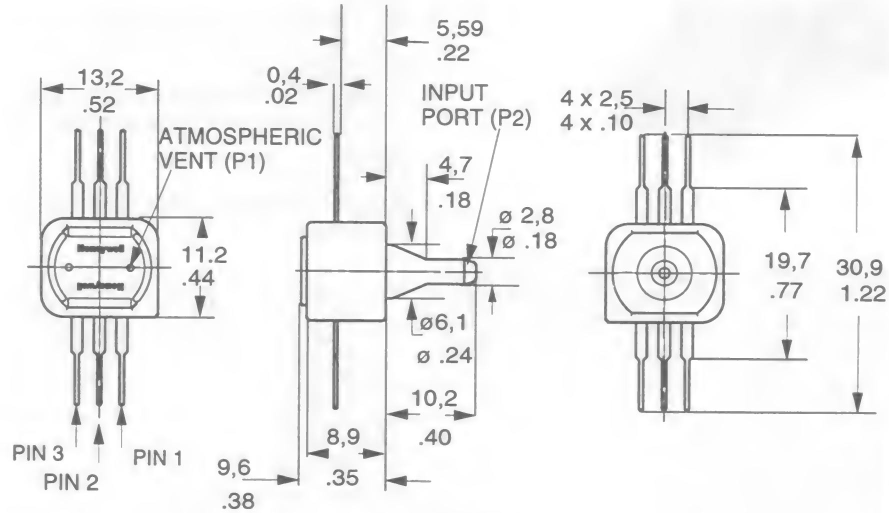
Note 2: Total accuracy is the maximum deviation from the 25°C reference transfer function at any pressure or temperature over the specified ranges. This calculation includes null, span, linearity, hysteresis, repeatability, null shift, and span shift.

ELECTRICAL CONNECTION



NOTES:
1. Square corner marks pin 1 (Vs).
2. Output is short circuit protected.

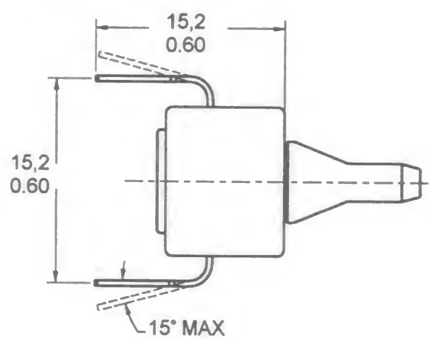
MOUNTING DIMENSIONS (for reference only) mm/In.



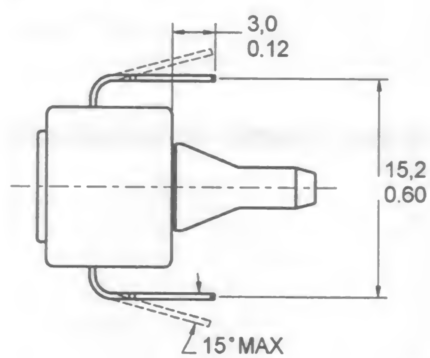
Lead Style 1

NOTE:
P1 - DRY GASES ONLY: Media must be compatible with epoxy based adhesive.
P2 - Media must be compatible with glass, silicon, stainless steel, invar, Sn/Ni plating or Sn/Ag solder.

Lead Style 2



Lead Style 3



Amplified

Pressure Sensors
Monolithic Signal Conditioned

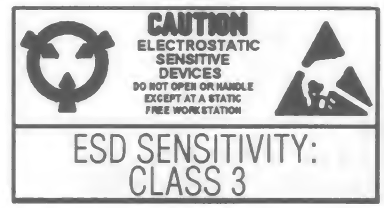
NEW

FEATURES
- Operating temperature range – −45° to +125°C (−49° to +257°F)
- Monolithic design
- Compatible with media from dry air and water to refrigerant coolants and engine fuels
- 0.2% accuracy
- Rugged stainless steel and brass construction

The 4000 PC Series Package allows use in harsh environmental conditions, such as industrial and off-road applications. The sensor is available with a Packard Connector 12078090 or a connector harness with leadwires.

PERFORMANCE CHARACTERISTICS

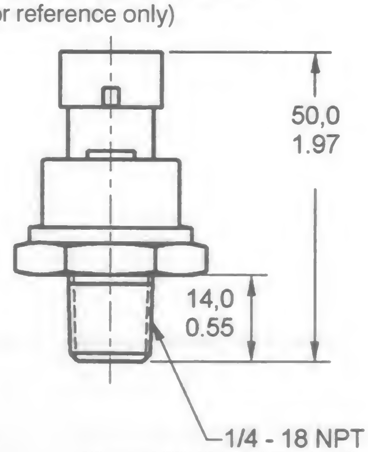
Pressure Range	±50 mm Hg	0-15 psi	0-100 psi	0-150 psi	0-250 psi
Overpressure, max.	±170 mm Hg	45 psi	200 psi	300 psi	500 psi
Supply Voltage	5 VDC ±0.25				
Supply Current	10 mA max.				
Output Source Current	0.5 mA max.				
Output Sink Current	1.0 mA max.				
Operating Temperature	−45° to +125°C (−49° to +257°F)				
Storage Temperature	−55° to +125°C (−67° to +257°F)				
Hysteresis & Repeatability	0.15% Span, Typ.				
Ratiometricity (at 4.75 to 5.25 Supply Voltage)	±0.25% Span, Typ.				
Output Load Capacitance	0.05 microfarads, max.				
Full Scale					
	−50 mm Hg	0.50 VDC Typ.			
	+50 mm Hg	4.50 ± 0.12 VDC Typ.			
	All other pressure ranges	4.50 VDC Typ.			
Media Compatibility	Media must be compatible with fluorosilicone, fluorocarbon, glass, silicon, stainless steel, invar, Sn/Ni plating or Sn/Ag solder				



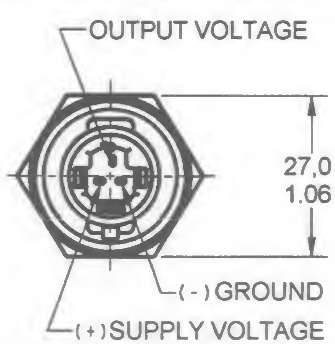
4000PC SERIES ORDER GUIDE

Catalog Listing	Gage Pressure Range	Termination
4040PC001B4D	±50 mm Hg	Packard Connector
4040PC001B5D	±50 mm Hg	Connector with Leadwires
4040PC015G4D	0 to 15 psi	Packard Connector
4040PC015G5D	0 to 15 psi	Connector with Leadwires
4040PC100G4D	0 to 100 psi	Packard Connector
4040PC100G5D	0 to 100 psi	Connector with Leadwires
4040PC150G4D	0 to 150 psi	Packard Connector
4040PC150G5D	0 to 150 psi	Connector with Leadwires
4040PC250G4D	0 to 250 psi	Packard Connector
4040PC250G5D	0 to 250 psi	Connector with Leadwires

MOUNTING DIMENSIONS
(for reference only)



ELECTRICAL CONNECTIONS



Leadwire Color Code
RED – Supply Voltage (+)
BLACK – Ground (–)
GREEN – Output

NOTE:
Output is short circuit protected.

Pressure Sensors
Monolithic Signal Conditioned

OUTPUT PERFORMANCE CHARACTERISTICS @ 25°C, 5VDC (unless otherwise noted)

Pressure Range	Null (VDC)	Span (VDC)	Sensitivity, Typ.	Linearity, B.F.S.L. (% Span) Max.		Null Shift (% Span) Max.	Span Shift (% Span) Max.	Combined Null and Span Shift (% Span) Max.
±50 mm Hg	2.50 ± 0.050	4.00 Typ.	40.0 mV/mm Hg	0.80	+25° to +50°C	±1.50	±1.50	—
					+25° to 0°C	±1.50	±1.50	—
					+25° to −18°C	±2.00	±0.75	±2.00
					+25° to +63°C	±2.00	±0.75	±2.00
0 to 15 psi	0.50 ± 0.11	4.00 ± 0.11	266.6 mV/psi	0.20	+25° to −45°C	±2.75	±1.00	±3.00
					+25° to +85°C	±2.75	±1.00	±3.00
					+25° to +125°C	—	—	—
					+25° to −18°C	±1.25	±0.75	±1.50
					+25° to +63°C	±1.25	±0.75	±1.50
0 to 100 psi	0.50 ± 0.04	4.00 ± 0.09	40.0 mV/psi	0.10	+25° to −45°C	±2.00	±1.00	±2.50
					+25° to +85°C	±2.00	±1.00	±2.50
					+25° to +125°C	±3.00	±2.00	±3.00
					+25° to −18°C	±0.75	±0.75	±0.75
					+25° to +63°C	±0.75	±0.75	±0.75
0 to 150 psi	0.50 ± 0.04	4.00 ± 0.07	26.6 mV/psi	0.10	+25° to −45°C	±1.00	±1.00	±1.00
					+25° to +85°C	±1.00	±1.00	±1.00
					+25° to +125°C	±1.50	±1.50	±1.50
					+25° to −18°C	±0.75	±0.75	±0.75
					+25° to +63°C	±0.75	±0.75	±0.75
0 to 250 psi	0.50 ± 0.04	4.00 ± 0.07	16.0 mV/psi	0.10	+25° to −45°C	±1.00	±1.00	±1.00
					+25° to +85°C	±1.00	±1.00	±1.00
					+25° to +125°C	±2.00	±2.00	±3.00

Amplified

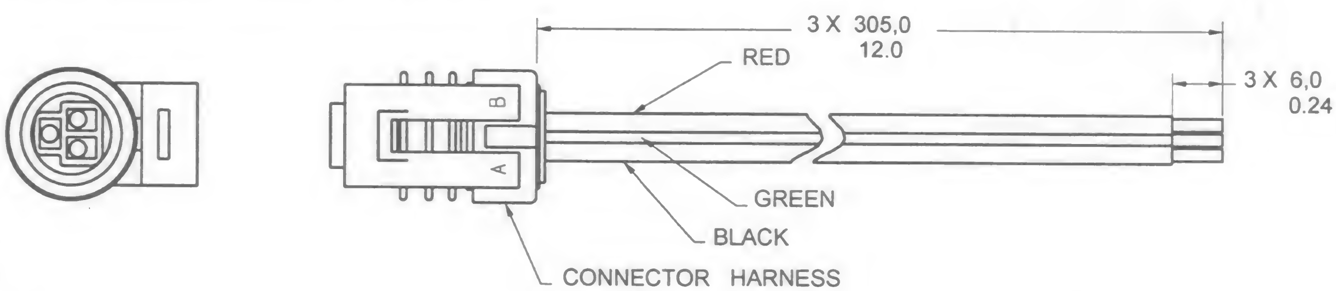
PERFORMANCE SPECIFICATIONS, TEMPERATURE/ACCURACY

Temperature Range	Total Accuracy (% Span) Max.			
	0 to 15 psi	0 to 100 psi	0 to 150 psi	0 to 250 psi
25°C	±0.4 (RSS)	±0.2 (RSS)	±0.2 (RSS)	±0.2 (RSS)
−18° to +63°C	±4.0	±2.5	±2.0	±2.0
−45° to +85°C	±4.0	±2.5	±2.0	±2.0
−45° to +125°C		±3.0	±2.5	±3.0

Note 1: Accuracy at 25°C is defined as RSS error for linearity, hysteresis, and repeatability.

Note 2: Total accuracy is the maximum deviation from the 25°C reference transfer function at any pressure or temperature over the specified ranges. This calculation includes null, span, linearity, hysteresis, repeatability, null shift, and span shift.

PC-15191 4000PC CONNECTOR HARNESS (for reference only)



Pressure Sensors
Monolithic Signal Conditioned

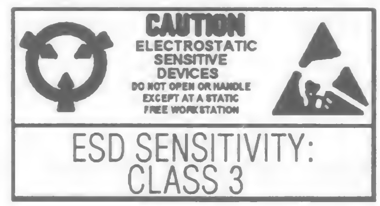
SOON TO BE INTRODUCED!

The 5000PC Series package allows use in harsh environmental conditions, such as industrial and off-road applications. The sensor is available with a Packard connector 12078090 or an integral connector with leadwires.

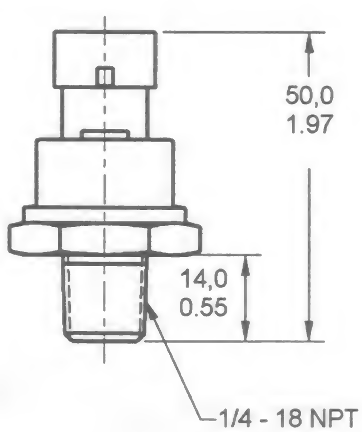
FEATURES
- Operating temperature range – −45° to +125°C (−49° to +257°F)
- Monolithic design
- Compatible with media from dry air and water to refrigerant coolants and engine fuels
- 0.2% accuracy
- Rugged stainless steel and brass construction
- Enhanced EMI performance
- Enhanced sealing for splash protection

PRELIMINARY PERFORMANCE CHARACTERISTICS

Pressure Range	0-15 psi	0-100 psi	0-150 psi	0-250 psi
Overpressure, max.	45 psi	200 psi	300 psi	500 psi
Supply Voltage	5 VDC ±0.25			
Supply Current	10 mA max.			
Output Source Current	0.5 mA max.			
Output Sink Current	1.0 mA max.			
Operating Temperature	−45° to +125°C (−49° to +257°F)			
Storage Temperature	−55° to +125°C (−67° to +257°F)			
Hysteresis & Repeatability	0.15% Span, Typ.			
Ratiometricity (at 4.75 to 5.25 Supply Voltage)	±0.25% Span, Typ.			
Full Scale				
	−50 mm Hg		0.50 VDC Typ.	
	+50 mm Hg		4.50 ± 0.12 VDC Typ.	
	All other pressure ranges		4.50 VDC Typ.	
Media Compatibility	Media must be compatible with fluorosilicone, fluorocarbon, glass, silicon, stainless steel, invar, Sn/Ni plating or Sn/Ag solder			



MOUNTING DIMENSIONS
(for reference only)



Pressure Sensors
Absolute, Differential, Gage, Vacuum Gage/Amplified

FEATURES
- PCB terminals on opposite side from the ports
- Fully signal conditioned

140PC SERIES PERFORMANCE CHARACTERISTICS at 8.0 ±0.01 VDC Excitation, 25°C

	Min.	Typ.	Max.	Units
Excitation	7.00	8.00	16.0	VDC
Supply Current	---	8.00	20.0	mA
Current Sourcing Output	---	---	10	mA
Null Offset (141/142PC)	0.95	1.00	1.05	V
Null Offset (143PC) *	3.45	3.50	3.55	V
Null Offset 142PC15A @ 2 psia 142PC30A @ 2 psia	 1.62 1.28	 1.67 1.33	 1.72 1.38	 V V
Output at Full Pressure	5.90	6.00	6.10	V
Span† (141/142PC)	4.95	5.00	5.05	V
Span† (143PC) *	---	5.00	---	V
Span 142PC15A (2 to 15 psia) 142PC30A (2 to 30 psia)	 4.28 4.62	 4.33 4.67	 4.48 4.72	 V V
Ratiometricity Error 7 to 8 V or 8 to 9 V 9 to 12 V	 --- ---	 ±0.50 ±2.00	 --- ---	 %Span
Stability over One Year	---	±0.50	---	%Span
Response Time	---	---	1.00	msec
Common Mode Pressure **	---	---	40	psi
Weight	---	28	---	grams
Short Circuit Protection	Output may be shorted indefinitely to ground			
Output Ripple	None, DC device			
Ground Reference	Supply and output are common			

* Positive and negative pressure measurement.
** Higher common mode pressures possible if sensor is not used over entire operating temperature range.
† Span is defined as the algebraic difference between end points. Please note: actual output is 1 V to 6 V (at 8.00 ±0.01 VDC). Span is then 5V.

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40° to +85°C (−40° to +185°F)
Storage Temperature	−55° to +125°C (−67° to +257°F)
Compensated Temperature	−18° to +63°C (0° to +145°F)
Shock	MIL-STD-202, Method 213 (50 g, half sine, 6 msec)
Vibration	MIL-STD-202, Method 204 (10 to 2000 Hz at 10 g)
Media	P2 port Wetted materials; polyester housing, epoxy adhesive, silicon, borosilicate glass, and silicon-to-glass bond *
	P1 port Dry gases only

* Liquid media containing some highly ionic solutions could potentially neutralize the chip-to-glass tube bond.

Pressure Sensors
Absolute, Differential, Gage, Vacuum Gage/Amplified

140PC SERIES ORDER GUIDE, VACUUM GAGE TYPE

Catalog Listing	Pressure Range psi	Shift Null, Sensitivity, Combined**				Sensitivity V/psi	Overpressure psi Max.	Linearity, B.F.S.L.		Repeatability & Hysteresis %Span Typ.
		25 to 5° 25 to 45°C		25 to −18° 25 to +63°C	25 to −40° 25 to 85°C			P2 > P1 %Span	P2 < P1 %Span	
		Typ.	Max.	Max.	Max.			Max.	Max.	
141PC01G	0-−1	---	±1.50	---	---	5.000	20	---	±0.75	±0.30
141PC05G	0-−5	±0.50	---	±1.00	±2.00	1.000	20	---	±0.75	±0.25
141PC15G	0-−15	±0.50	---	±1.00	±2.00	0.333	45	---	±0.40	±0.15

140PC SERIES ORDER GUIDE, GAGE TYPE

Catalog Listing	Pressure Range psi	Shift Null, Sensitivity, Combined**				Sensitivity V/psi	Overpressure psi Max.	Linearity, B.S.F.L.		Repeatability & Hysteresis %Span Typ.
		25 to 5° 25 to 45°C		25 to −18° 25 to +63°C	25 to −40° 25 to 85°C			P2 > P1 %Span	P2 < P1 %Span	
		Typ.	Max.	Max.	Max.			Max.	Max.	
142PC01G	0-1	---	±1.50	---	---	5.000	20	±0.75	---	±0.30
142PC02G	0-2	---	±1.50	---	---	2.500	20	±0.75	---	±0.30
142PC05G	0-5	±0.50	---	±1.00	±2.00	1.000	20	±1.50	---	±0.25
142PC15G	0-15	±0.50	---	±1.00	±2.00	0.333	45	±0.75	---	±0.15
142PC30G	0-30	±0.50	---	±1.00	±2.00	0.167	60	±0.75	---	±0.15
143PC03G	±2.5	---	---	±1.00	±1.50	1.000	20	±0.75	---	±0.25
143PC05G	±5	---	---	±1.00	±1.50	0.500	30	±0.75	---	±0.15
143PC15G	±15	---	---	±1.00	±1.50	0.177	50	±0.75	---	±0.15

140PC SERIES ORDER GUIDE, DIFFERENTIAL TYPE

Catalog Listing	Pressure Range psi	Shift Null, Sensitivity, Combined**				Sensitivity V/psi	Overpressure psi Max.	Linearity, B.F.S.L.		Repeatability & Hysteresis %Span Typ.
		25 to 5° 25 to 45°C		25 to −18° 25 to +63°C	25 to −40° 25 to 85°C			P2 > P1 %Span	P2 < P1 %Span	
		Typ.	Max.	Max.	Max.			Max.	Max.	
142PC01D	0-1	---	±1.50	---	---	5.000	20	±0.75	±0.40	±0.30
142PC02D	0-2	---	±1.50	---	---	2.500	20	±0.75	±0.40	±0.30
142PC05D	0-5	±0.50	---	±1.00	±2.00	1.000	20	±1.50	±0.75	±0.25
142PC15D	0-15	±0.50	---	±1.00	±2.00	0.333	45	±0.75	±0.40	±0.15
142PC30D	0-30	±0.50	---	±1.00	±2.00	0.167	60	±0.75	±0.40	±0.15
143PC03D	±2.5	---	---	±1.00	±1.50	1.000	20	±0.75	±0.40	±0.25
143PC05D	±5	---	---	±1.00	±1.50	0.500	30	±0.75	±0.40	±0.15
143PC15D	±15	---	---	±1.00	±1.50	0.177	50	±0.75	±0.40	±0.15

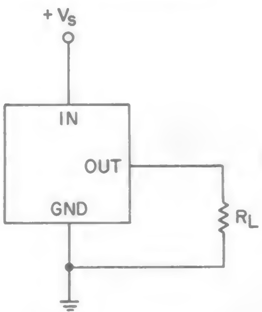
140PC SERIES ORDER GUIDE, ABSOLUTE TYPE*

Catalog Listing	Pressure Range psia	Shift Null, Sensitivity, Combined**				Sensitivity V/psi	Overpressure psi Max.	Linearity, B.F.S.L.		Repeatability & Hysteresis %Span Typ.
		25 to 5° 25 to 45°C		25 to −18° 25 to +63°C	25 to −40° 25 to 85°C			P2 > P1 %Span	P2 < P1 %Span	
		Typ.	Max.	Max.	Max.			Max.	Max.	
142PC15A	0-15	±0.50	---	±1.00	±2.00	0.333	45	---	±0.40	±0.15
142PC30A	0-30	±0.50	---	±1.00	±2.00	0.167	60	---	±0.40	±0.15

*Tested at 2 psia reference
**% Span specification applies to each shift independently. (Null, sensitivity, or combined).

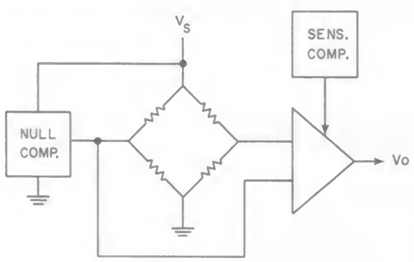
Pressure Sensors
Absolute, Differential, Gage, Vacuum Gage/Amplified

ELECTRICAL CONNECTION
Voltage Excitation

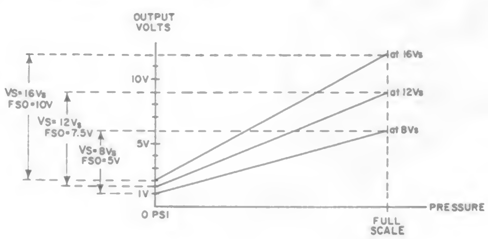


NOTES
1. Terminals are labeled on the sensor.
2. Input and output share a common ground.
3. R_L must be greater than or equal to 3000 ohms.

INTERNAL CIRCUITRY



RATIOMETRICITY



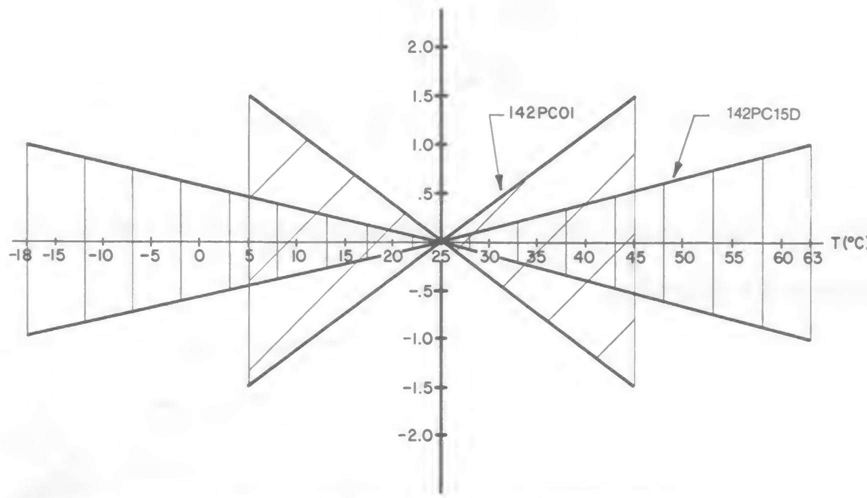
Ratiometricity refers to the output voltage being directly proportional to the supply voltage. 140PC sensors in this catalog are calibrated at 8 VDC supply voltage to provide a 1-6 volt (5V Span) output swing. For example, if supply increases by 50% to 12 VDC, the output voltage increases by 50% to 1.5-9 volts (7.5 V Span).

NOTE
The output is not perfectly ratiometric. See specifications for the degree of error.

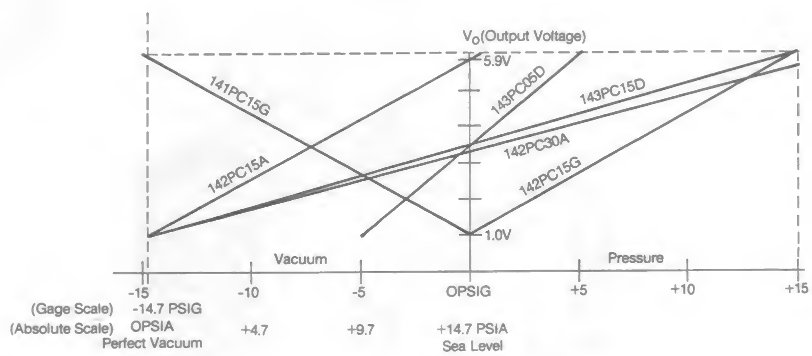
NULL AND SENSITIVITY TEMPERATURE SHIFT
Amplified pressure sensors are 100% tested to insure that the maximum null and sensitivity temperature shift does not exceed the specification. The diagram below illustrates how null and sensitivity shift relates to temperature. Note that the maximum shift occurs at temperature extremes. Therefore, if a sensor is not exposed to the entire temperature range, the maximum null and sensitivity shift will actually be less than the value specified.

This diagram indicates the temperature shift pertaining to a few listings. Maximum null and sensitivity shift varies from listing to listing.

NULL AND SENSITIVITY SHIFT (% F.S.O.)



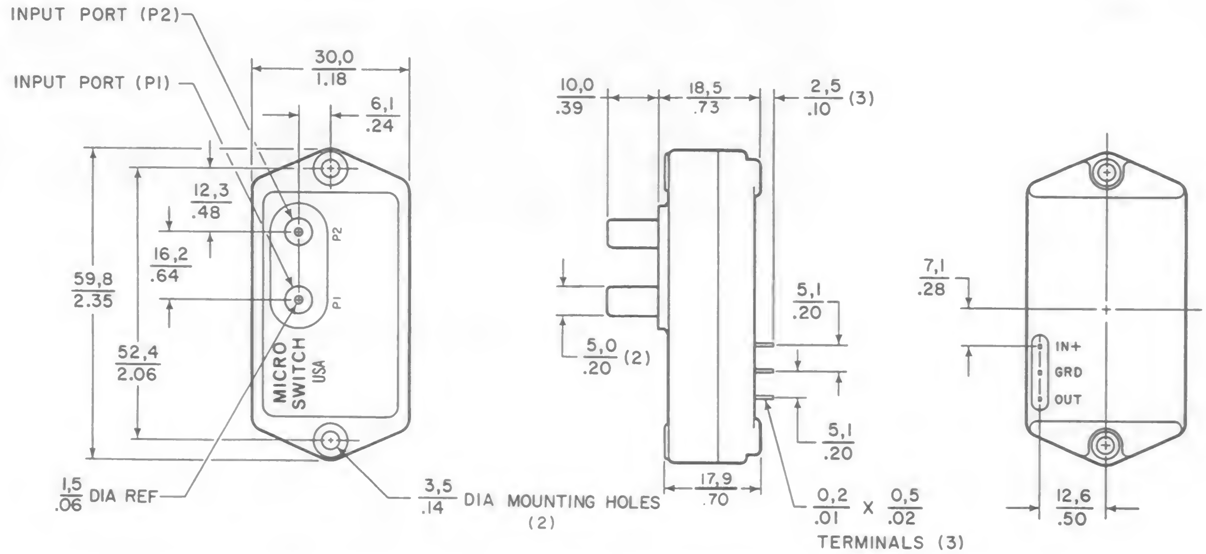
SCALING OF 140PC SERIES SENSORS WITH 8V EXCITATION



142PC15A	Absolute	V_o = 1 V at 0 psia & 6 V at 15 psia
142PC30A	Absolute	V_o = 1 V at 0 psia & 6 V at 30 psia
142PC15G	Gage	V_o = 1 V at 0 psig & 6 V at 15 psig
141PC15G	Vacuum Gage	V_o = 1 V at 0 psig & 6 V at −15 psig
143PC05D	Differential	V_o = 1 V at −5 psig & 6 V at 5 psig
143PC15D	Differential	V_o = 1 V at −15 psig & 6 V at 15 psig

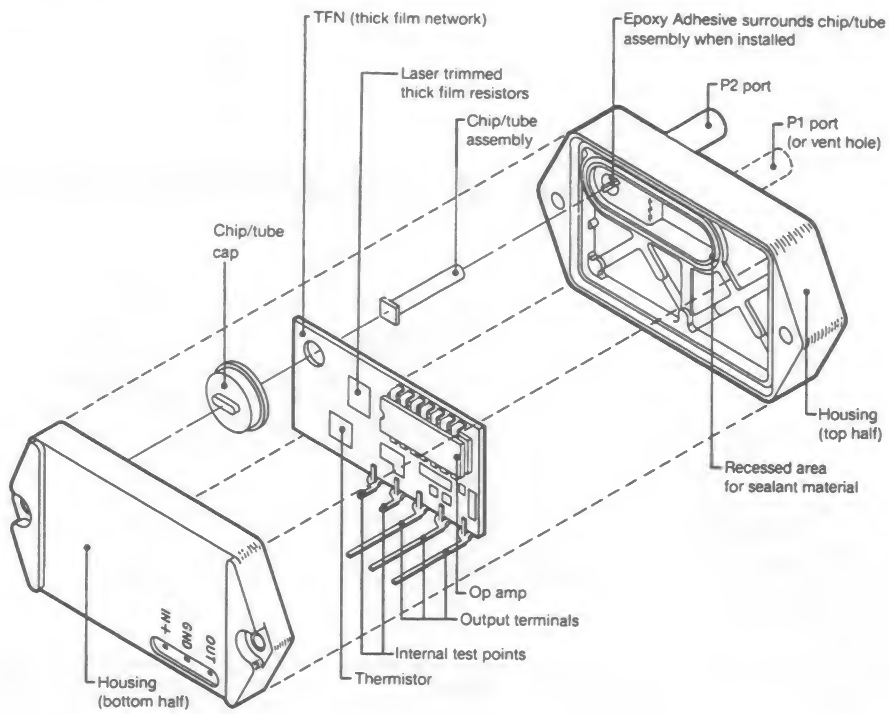
NOTE: 141PC sensors are scaled for vacuum pressure on P2.
142PC sensors are scaled for greater pressure on the P2 side of the chip. Input pressures on absolute units are applied to the P1 port.
Other scalings available upon request.

MOUNTING DIMENSIONS (For reference only)



Dimensions shown apply to Differential and Absolute versions. Gage units are identical, except the P1 port is absent.

140PC CONSTRUCTION



Pressure Sensors

160PC Series

Low Pressure Differential, Gage, Vacuum Gage/Amplified

FEATURES
- Low pressure measurement
- PCB terminals on opposite side from the ports
- Fully signal conditioned

Amplified

160PC SERIES PERFORMANCE CHARACTERISTICS at 8.0 ±0.01 VDC Excitation, 25°C (Exception 163PC at 10 ±0.01 VDC Excitation, 25°C)

	Min.	Typ.	Max.	Units
Excitation	6.00	8.00	16	VDC
Supply Current	---	8.00	20	mA
Current Sourcing Output	---	---	10	mA
Null Offset (161/162/164PC) *	0.95	1.00	1.05	V
Null Offset (163PC) **	3.45	3.50	3.55	V
Output at Full Pressure (161/162/164PC)	5.90	6.00	6.10	V
Output at Full Vacuum (163PC)	0.80	1.00	1.20	V
Span (161/162/164PC)	4.85	5.00	5.15	V
Span (163PC) **	---	5.00	---	V
Ratiometricity Error 7 to 8 V or 8 to 9 V 9 to 12 V	 --- ---	 ±0.50 ±2.00	 --- ---	 % Span
Stability over One Year	---	±0.50	---	% Span
Response Time	---	---	1.00	msec
Weight	---	28	---	grams
Short Circuit Protection	Output may be shorted indefinitely to ground			
Output Ripple	None, DC device			
Ground Reference	Supply and output are common			

* Positive (or negative) pressure measurement.
** Positive AND negative pressure measurement.

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40° to +85°C (−40° to +185°F)	
Storage Temperature	−55° to +125°C (−67° to +257°F)	
Compensated Temperature	−18° to +63°C (0° to +145°F)	
Shock	MIL-STD-202, Method 213 (50 g, half sine, 6 msec)	
Vibration	MIL-STD-202, Method 204 (10 to 2000 Hz at 10 g)	
Media	P2 port	Wetted materials; polyester housing, epoxy adhesive, silicon, borosilicate glass,and silicon-to-glass bond*
	P1 port	Dry gases only

* Liquid media containing some highly ionic solutions could potentially neutralize the chip-to-glass tube bond.

160PC SERIES ORDER GUIDE, VACUUM GAGE AND GAGE TYPE

Catalog Listing	Pressure Range "H_2O	Shift Null, Sensitivity, Combined** 25 to 5° 25 to 45°C Max.	25 to −18° 25 to +63°C Max.	25 to −40° 25 to 85°C Max.	Sensitivity V/"H_2O	Overpressure psi Max.	Linearity, B.F.S.L. %Span P2 > P1 Max.	P2 < P1 Max.	Repeatability & Hysteresis %Span Typ.
161PC01D	0-27.68	---	±1.00	±2.00	0.18	5	---	±1.00	±0.15 Vacuum Gage
162PC01G	0-27.68	---	±1.00	±2.00	0.18	5	---	±1.00	±0.15 Gage

160PC SERIES ORDER GUIDE, DIFFERENTIAL TYPE

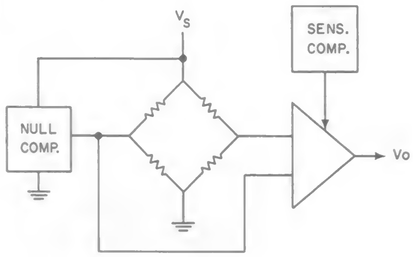
Catalog Listing	Pressure Range "H_2O	Shift Null, Sensitivity, Combined** 25 to 5° 25 to 45°C Max.	25 to −18° 25 to +63°C Max.	25 to −40° 25 to 85°C Max.	Sensitivity V/"H_2O	Overpressure psi Max.	Linearity, B.F.S.L. %Span P2 > P1 Max.	P2 < P1 Max.	Repeatability & Hysteresis %Span Typ.
162PC01D	0-27.68	---	±1.00	±2.00	0.18	5	±2.00	---	±0.15
163PC01D36	±5	±1.00	---	---	0.50	5	±2.00	±1.00	±0.25
164PC01D37	0-10	±1.00	---	---	0.50	5	±2.00	---	±0.25
163PC01D75	±2.5	±1.25	---	---	1.00	5	±2.00	±1.00	±0.25
164PC01D76	0-5	±1.25	---	---	1.00	5	±2.00	---	±0.25

160PC SERIES ORDER GUIDE, DIFFERENTIAL TYPE @ 10 VDC ±0.01 EXCITATION, 25°C

Catalog Listing	Pressure Range cmH_2O	Shift Null, Sensitivity, Combined** 25 to 5° 25 to 45°C Max.	25 to −18° 25 to +63°C Max.	25 to −40° 25 to 85°C Max.	Sensitivity V/cmH_2O	Overpressure cmH_2O Max.	Linearity, B.F.S.L. %Span P2 > P1 Max.	P2 < P1 Max.	Repeatability & Hysteresis %Span Typ.
163PC01D48	−20 to +120	±0.75*	---	---	0.36	350	±1.5	---	±0.15

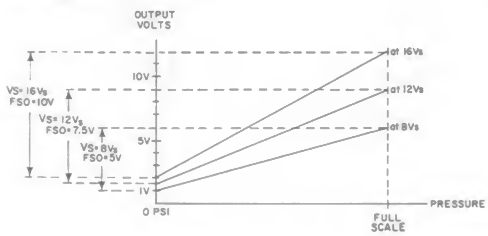
*Null shift. Span shift is ±1.00/Span
**% Span specification applies to each shift independently (Null, Sensitivity, or Combined)

INTERNAL CIRCUITRY



NOTES
1. Terminals are labeled on the sensor.
2. Input and output share a common ground.
3. R_L must be greater than or equal to 3000 ohms.

RATIOMETRICITY



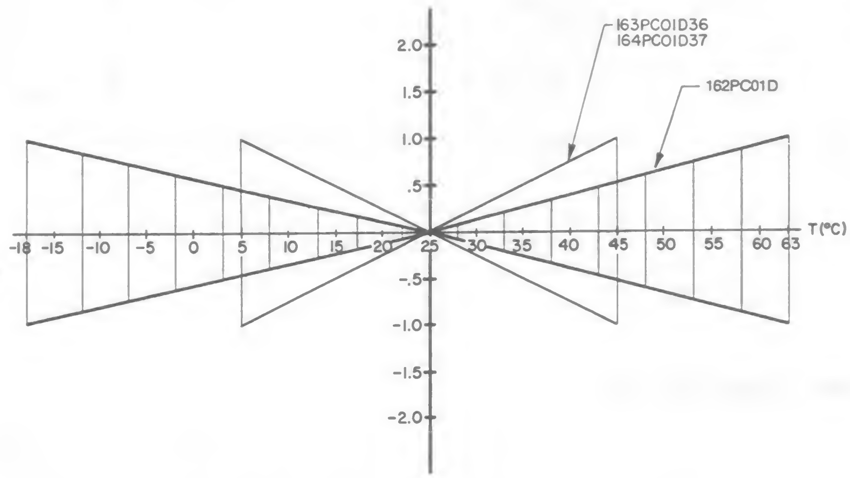
Ratiometricity refers to the output voltage being directly proportional to supply voltage. 160PC sensors in this catalog are calibrated at 8 VDC supply voltage (except 163PC) to provide a 1-6 volt (5 V Span) output swing. For example, if supply increases by 50% to 12 VDC, the output voltage increased by 50% to 1.5-9 volts (7.5 V Span).

NOTE
The output is not perfectly ratiometric. See Accuracy specifications for the degree of error.

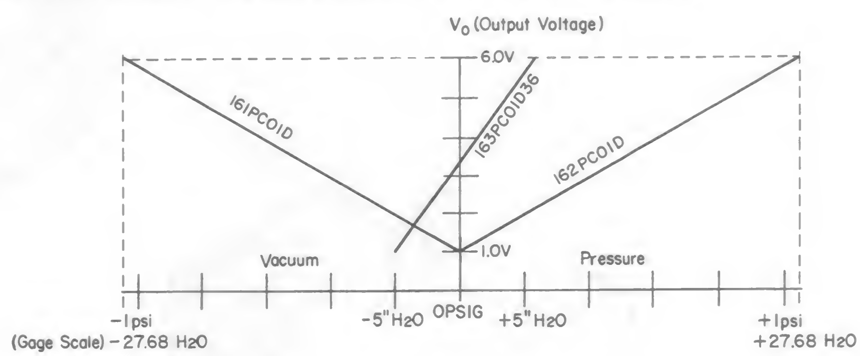
NULL AND SENSITIVITY TEMPERATURE SHIFT

Amplified pressure sensor are 100% tested to insure that the maximum null and sensitivity temperature shift does not exceed the specification. The diagram below illustrates how null and sensitivity shift relates to temperature. Note that the maximum shift occurs at temperature extremes. Therefore, if a sensor is not exposed to the entire temperature range, the maximum null and sensitivity shift will actually be less than the value specified.

This diagram indicates the temperature shift pertaining to a few listings. Maximum null and sensitivity shift varies from listing to listing.



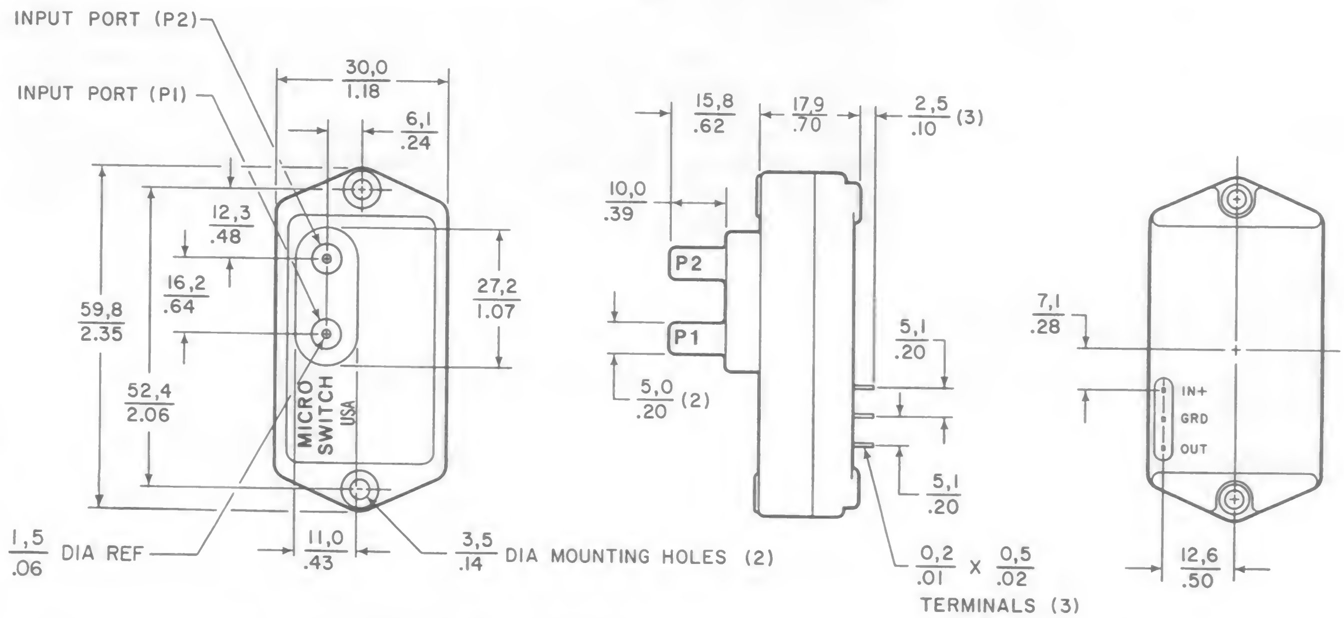
SCALING OF 160PC SERIES SENSORS WITH 8V EXCITATIONS



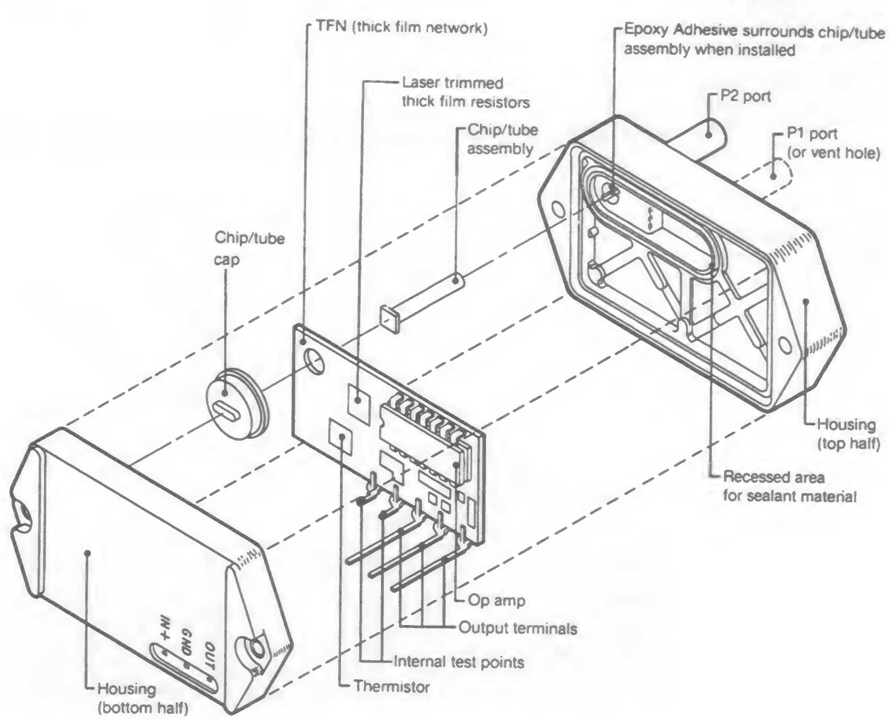
161PC01D	Vacuum Gage	V_o = 1 V at 0 psig & 6 V at −1 psig
162PC01D	Differential	V_o = 1 V at 0 psig & 6 V at 1 psig
163PC01D36	Differential	V_o = 1 V at −5" H_2O & 6 V at −5" H_2O

NOTE: 161PC sensors are scaled for greater pressure on the P1 side of the chip. 162PC sensors are scaled for greater pressure on the P2 side of the chip. Other scalings available upon request.

MOUNTING DIMENSIONS (For reference only)



160PC CONSTRUCTION



Pressure Sensors

Miniature Absolute, Differential, Gage/Amplified

Terminal Mount Housing Mount

FEATURES
- Miniature plastic package
- Terminal and housing mount styles
- PCB termination
- Fully signal conditioned

180PC SERIES PERFORMANCE CHARACTERISTICS at 8.0 ±0.01 VDC Excitation, 25°C

	Min.	Typ.	Max.	Units
Excitation	7.00	8.00	16	VDC
Supply Current	---	---	6	mA
Current Sourcing Output	---	---	10	mA
Null Offset (184/185PC)	0.95	1.00	1.05	V
Null Offset (186PC)	3.45	3.50	3.55	V
Null Offset 185PC15AT @ 2 psia 185PC30AT @ 2 psia	 1.62 1.28	 1.67 1.33	 1.72 1.38	 V V
Output at Full Pressure (184/185PC, G,D)	5.90	6.00	6.15	V
Output at Full Pressure (185PC, A only)	5.85	6.00	6.15	V
Output at Full Pressure (186PC)	5.90	6.00	6.10	V
Span (184/185PC, G,D)	4.95	5.00	5.05	V
Span (185PC, A only)	4.90	5.00	5.10	V
Span (186PC)	---	5.00	---	V
Span (185PC15AT)	4.28	4.33	4.38	V
Span (185PC30AT)	4.62	4.67	4.72	V
Ratiometricity Error 7 to 8V or 8 to 9V 9 to 12V	 --- ---	 ±0.50 ±2.00	 --- ---	 % Span % Span
Temperature Error (Combined null and span)	−2%	0	+2%	% Span
Stability over One Year	---	±0.50	---	% Span
Response Time	---	---	1.00	msec
Weight	---	12	---	grams
Short Circuit Protection	Output may be shorted indefinately to ground			
Output Ripple	None, DC device			
Ground Reference	Supply and output are common			

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40° to +85°C (−40° to +185°F)	
Storage Temperature	−55° to +125°C (−67° to +257°F)	
Compensated Temperature	0° to +50°C (32° to +122°F)	
Shock	MIL-STD-202, Method 213 (50 g, half sine, 6 msec)	
Vibration	MIL-STD-202, Method 204 (10 to 2000 Hz at 10 g)	
Media	P2 port	Wetted materials; polyester housing, epoxy adhesive, silicon, borosilicate glass, and silicon-to-glass bond*
	P2 port	Absolute only: Factory sealed vacuum reference, no connection
	P1 port	Dry gases only

*Liquid media containing some highly ionic solutions could potentially neutralize the chip-to-glass tube bond.

Pressure Sensors
Miniature Absolute, Differential, Gage/Amplified

184PC SERIES ORDER GUIDE, VACUUM GAGE TYPE

Catalog Listing	Pressure Range psi	Overpressure psi Max.	Linearity, % Span	
			P2 > P1 Max.	P2 < P1 Max.
184PC05GT	0-−5	20	---	±1.00
184PC15GT	0-−15	45	---	±1.00

185PC SERIES ORDER GUIDE, DIFFERENTIAL TYPE, P2 > P1

Catalog Listing	Pressure Range psi	Overpressure psi Max.	Linearity, % Span	
			P2 > P1 Max.	P2 < P1 Max.
185PC05DT	0-5	20	±2.00	±1.00
185PC15DT	0-15	45	±2.00	±1.00
185PC30DT	0-30	60	±1.50	±0.75

186PC SERIES ORDER GUIDE, BI-DIRECTIONAL TYPE, P2-P1

Catalog Listing	Pressure Range psi	Overpressure psi Max.	Linearity, % Span	
			P2 > P1 Max.	P2 < P1 Max.
186PC03DT	±2.5	20	±2.00	±1.00
186PC05DT	±5.0	20	±2.00	±1.00
186PC15DT	±15	45	±2.00	±1.00

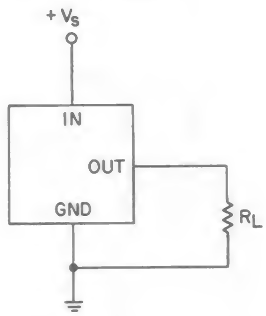
185PC SERIES ORDER GUIDE, ABSOLUTE TYPE

Catalog Listing	Pressure Range psi	Overpressure psi Max.	Linearity, % Span	
			P2 > P1 Max.	P2 < P1 Max.
185PC15AT	0-15	45	---	±1.00
185PC30AT	0-30	60	---	±0.75

HOW TO ORDER
Catalog listings in the order guide are shown with mounting version **T** (terminal mount). **H** (housing mount) also available. Contact 800 number.

ELECTRICAL CONNECTIONS

Voltage Excitation



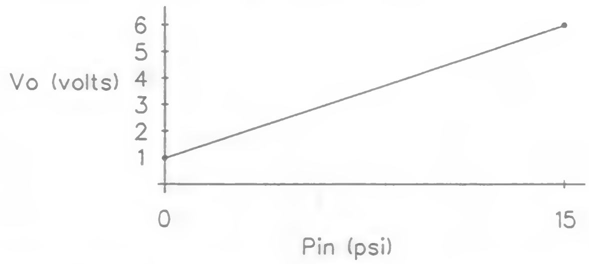
NOTES

1. Terminals are labeled on the sensor.
2. Input and output share a common ground.
3. R_L must be greater than or equal to 3000 ohms.

IDEAL OUTPUT AT Vs = 8.00 ± 0.01 VDC

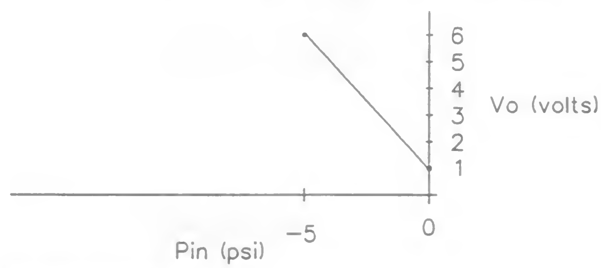
Differential

Example: 185PC15DT when P_{IN} = P2-P1



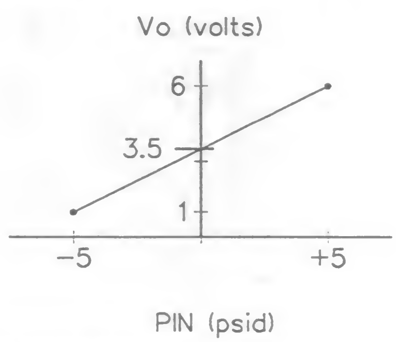
Vacuum Gage

Example: 184PC05GT where P2 = P_{IN} P1 = Ambient



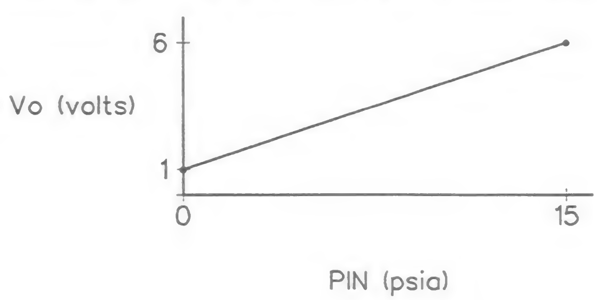
Bi-directional

Example: 186PC05DH where P_{IN} = P2-P1



Absolute

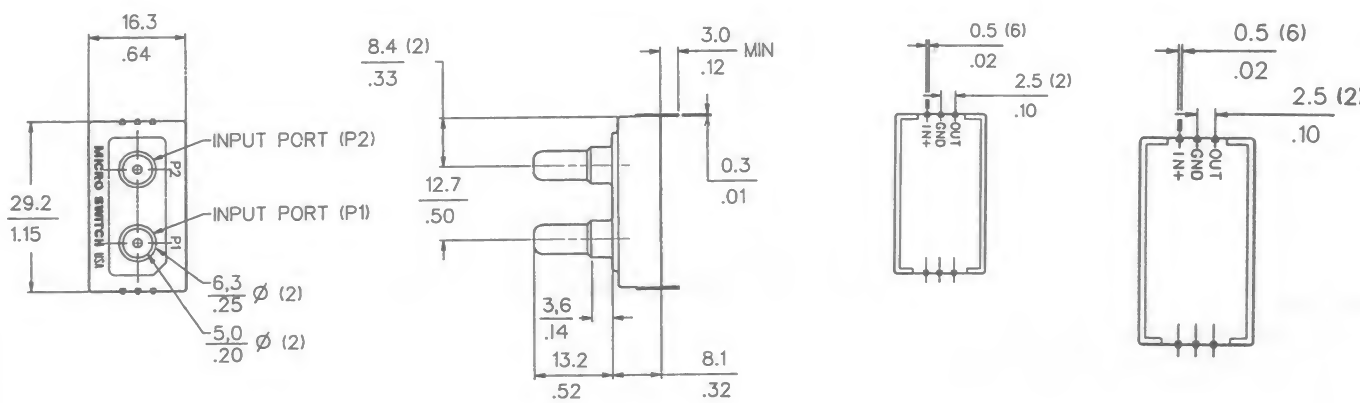
Example: 185PC15AP where P1 = P_{IN} P2 = Factory sealed vacuum



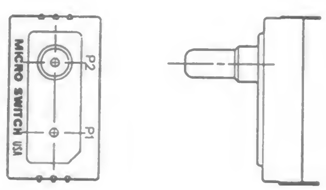
Amplified

MOUNTING DIMENSIONS 0.0 = mm / 0.00 = in.

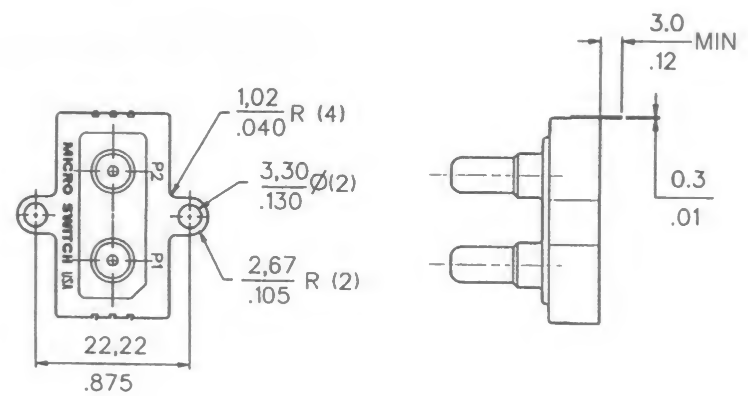
Terminal Mount (Differential "D" or Absolute "A" Housing)



(Gage "G" Housing)



Housing Mount



Pressure Sensors
Gage Amplified

NEW

FEATURES
- Manifold mount/O-ring sealed
- Fully signal conditioned
- PCB termination
- Operating temperature up to 125°C
- Glass chip tube (non-outgassing)

189PC PERFORMANCE CHARACTERISTICS @ 8.0 ±0.01 VDC Excitation, 25°C

	Min	Typ	Max	Units
Excitation	7.00	8.00	16.0	VDC
Supply Current	—	—	6	mA
Current Sourcing Output	—	—	10	mA
Null Offset	0.95	1.00	1.05	V
Output at Full Pressure	5.80	6.00	6.15	V
Ratiometricity Error 7 to 8V or 8 to 9V 9 to 12 V	 — —	 ±0.50 ±2.00	 — —	 % Span % Span
Temperature Error (Combined null and span)	−2	0	+2	% Span
Stability over One Year	—	±0.50	—	%Span
Response Time	—	—	1.00	mS
Weight	—	12	—	grams
Short Circuit Protection	Output may be shorted indefinitely to ground			
Output Ripple	None, DC Device			
Ground Reference	Supply and output are common			

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature		−40°C to +85°C (−40° to +185°F)
Storage Temperature		−55° to +125°C (−67° to +257°F)
Compensated Temperature		0° to +50°C (32° to +122°F)
Shock		MIL-STD-202, Method 213 (50g, half sine, 6 msec)
Vibration		MIL-STD-202, Method 204 (10 to 2000 Hz at 10 g)
Media	P2 port	Wetted materials; polyester housing, epoxy adhesive, silicon, borosilicate glass, and silicon-to-glass bond*

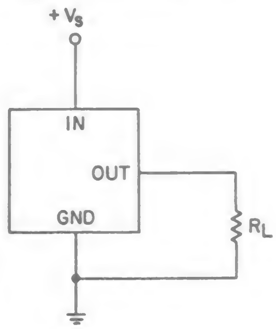
*Liquid media containing some highly ionic solutions could potentially neutralize the chip-to-glass tube bond.

189PC SERIES ORDER GUIDE GAGE TYPE

Catalog Listing	Pressure Range psi	Overpressure psi Max.	Linearity, %Span P2 > P1 Max.
189PC15GM	0-15	45	±2.00
189PC100GM	0-100	250	±1.50
189PC150GM	0-150	250	±1.50

Electrical Connections

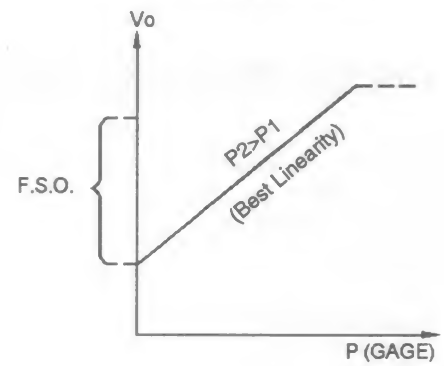
Voltage Excitation



Pin Designation

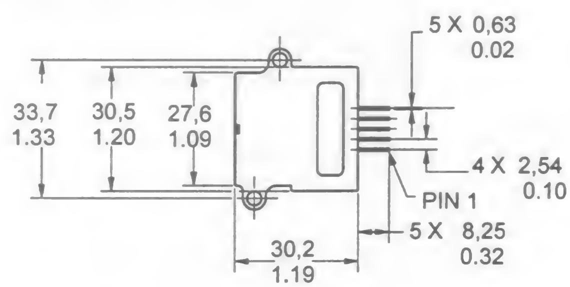
Pin 1 = V_{SS}
Pin 2 = V_{out}
Pin 3 = GND
Pin 4 = No Connect
Pin 5 = V_{CC}

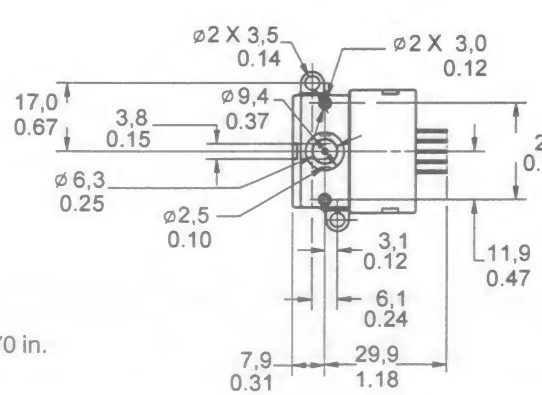
Pressure Reference Gage



NOTES
1. Input and output share a common ground.
2. R_L must be greater than or equal to 3000 ohms.

MOUNTING DIMENSIONS (for reference only)





O-Ring provided with sensor.
O-Ring Part Number: SS-12168.
O.D. of .114 in. and a cross section of .070 in.
Material is 70 Durometer Fluorocarbon.

Pressure Sensors
High Pressure Gage, Vacuum Gage/Amplified

FEATURES
- Internal O-Ring seals for contamination resistance
- Screw-in or flat-pack mounting
- Rugged aluminum housing

240PC SERIES PERFORMANCE CHARACTERISTICS at 8.0 ±0.01 VDC Excitation, 25°C

	Min.	Typ.	Max.	Units
Excitation	7.00	8.00	16.0	VDC
Supply Current	---	8.00	20.0	mA
Current Sourcing Output	---	---	10	mA
Null Offset (241/242PC) *	0.95	1.00	1.05	V
Null Offset (243PC) **	3.45	3.50	3.55	V
Output at Full Pressure **	5.80	6.00	6.20	V
Span (241/242PC)	4.80	5.00	5.20	V
Span (243PC)	---	±2.5	---	V
Ratiometricity Error 7 to 8 V or 8 to 9 V 9 to 12 V	 --- ---	 ±0.50 ±2.00	 --- ---	 %Span
Stability over One Year	---	±0.50	---	%Span
Response Time	---	---	1.00	msec
Weight	---	85	---	grams
Short Circuit Protection	Output may be shorted indefinitely to ground			
Output Ripple	None, DC device			
Ground Reference	Supply and output are common			

* Positive (or negative) pressure measurement
** Positive and negative pressure measurement

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40° to +85°C (−40° to +185°F)
Storage Temperature	−40° to +85°C (−40° to +185°F)
Compensated Temperature	−18° to +63°C (0° to +145°F)
Shock	MIL-STD-202, Method 213 (50 g, half sine, 6 msec)
Vibration	MIL-STD-202, Method 204 (10 to 2000 Hz at 10 g)
Media	P2 port Wetted materials; die-cast aluminum housing, O-ring seal, silicon, borosilicate glass, and silicon-to-glass bond*

* Liquid media containing some highly ionic solutions could potentially neutralize the chip-to-glass tube bond.

Amplified

Pressure Sensors
High Pressure Gage, Vacuum Gage/Amplified

241/242PC SERIES ORDER GUIDE, GAGE AND VACUUM GAGE, Buna-N O-Ring Port Seal

Catalog Listing	Pressure Range psi	Null & Sensitivity Shift (%Span) 25 to −18° 25 to +63°C Max.	Null & Sensitivity Shift (%Span) 25 to −40° 25 to 85°C Typ.	Sensitivity V/psi	Overpressure psi Max.	Linearity, %Span B.F.S.L., Max.	Repeatability & Hysteresis %Span Typ.
241PC15M*	0-−15	±1.0	±2.0	0.330	45	±1.50	±0.25
242PC15M*	0-15	±1.0	±2.0	0.330	45	±1.50	±0.25
242PC30M*	0-30	±1.0	±2.0	0.167	60	±1.50	±0.25
242PC60G	0-60	±1.5	±2.0	0.083	120	±0.50	±0.25
242PC100G	0-100	±1.0	±2.0	0.050	200	±0.50	±0.25
242PC150G	0-150	±1.5	±3.0	0.033	300	±0.50	±0.25
242PC250G	0-250	±1.0	±2.0	0.020	500	±0.50	±0.25

242PC SERIES ORDER GUIDE, GAGE, Ethylene propylene O-Ring Seal

Catalog Listing	Pressure Range psi	Null & Sensitivity Shift (%Span) 25 to −18° 25 to +63°C Max.	Null & Sensitivity Shift (%Span) 25 to −40° 25 to 85°C Typ.	Sensitivity V/psi	Overpressure psi Max.	Linearity, %Span B.F.S.L., Max.	Repeatability & Hysteresis %Span Typ.
242PC60GS	0-60	±1.5	±2.0	0.083	120	±0.50	±0.25
242PC100GS	0-100	±1.0	±2.0	0.050	200	±0.50	±0.25
242PC150GS	0-150	±1.5	±3.0	0.033	300	±0.50	±0.25
242PC250GS	0-250	±1.0	±2.0	0.020	500	±0.50	±0.25

243PC SERIES ORDER GUIDE, VACUUM GAGE, Buna-N Port Seal

Catalog Listing	Pressure Range psi	Null & Sensitivity Shift (%Span) 25 to −18° 25 to +63°C Max.	Null & Sensitivity Shift (%Span) 25 to −40° 25 to 85°C Typ.	Sensitivity V/psi	Overpressure psi Max.	Linearity, BFSL P2 > P1 Max.	Linearity, BFSL P2 < P1 Max.	Repeatability & Hysteresis %Span Typ.
243PC15M*	±15	±1	±2.0	0.167	50	±1.50	±0.75	±0.25

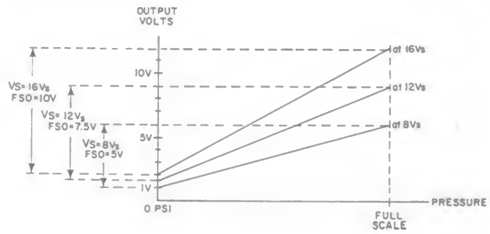
*Adhesive between thermoplastic and aluminum instead of O-ring seal.

PORT SEAL O-RING

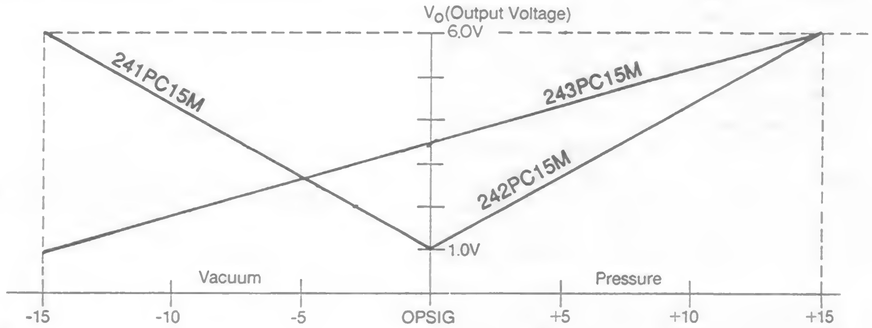
Material	Resistant To:
Buna-N (general use)	Petroleum products, freon 12 and others
Ethylene propylene	Phosphate esters and others

Pressure Sensors
High Pressure Gage, Vacuum Gage/Amplified

RATIOMETRICITY



SCALING OF 240PC SERIES WITH 8V EXCITATION



Ratiometricity refers to the output voltage being directly proportional to supply voltage. 240PC sensors in this catalog are calibrated at 8 VDC supply voltage to provide a 1-6 volt (5 V Span) output swing. For example, if supply increases by 50% to 12 VDC, the output voltage increased by 50% to 1.5-9 volts (7.5 V Span).

NOTE
The output is not perfectly ratiometric. See Accuracy specifications for the degree of error.

242PC15M	Gage	V_o = 1 V at 0 psig & 6 V at 15 psig
241PC15M	Vacuum Gage	V_o = 1 V at 0 psig & 6 V at −15 psig
243PC15M	Gage	V_o = 1 V at −15 psig & 6 V at 15 psig

NOTE: 241PC sensors are scaled for greater pressure on the P1 side of the chip. 242PC sensors are scaled for greater pressure on the P2 side of the chip.
Other scalings available upon request.

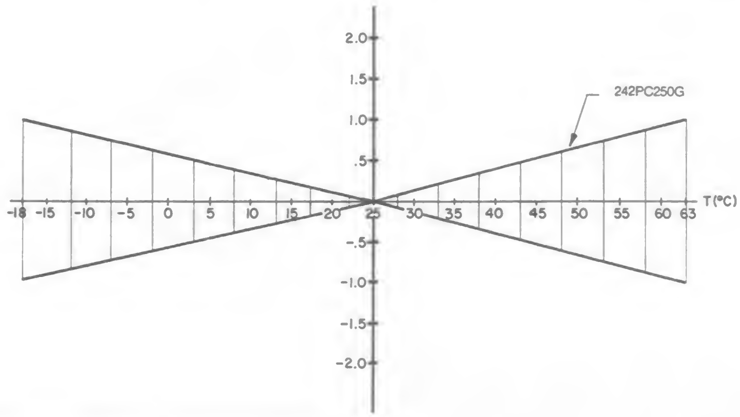
Amplified

NULL AND SENSITIVITY TEMPERATURE SHIFT

Amplified pressure sensors are 100% tested to ensure that the maximum null and sensitivity temperature shift does not exceed the specification. The diagram illustrates how null and sensitivity shift relates to temperature. Note that the maximum shift occurs at temperature extremes. Therefore, if a sensor is not exposed to the entire temperature range, the maximum null and sensitivity shift will actually be less than the value specified.

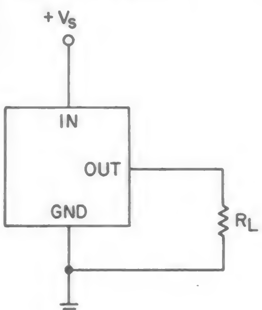
This diagram indicates the temperature shift pertaining to a few listings. Maximum null and sensitivity shift varies from listing to listing.

Null and Sensitivity Shift (% Span)

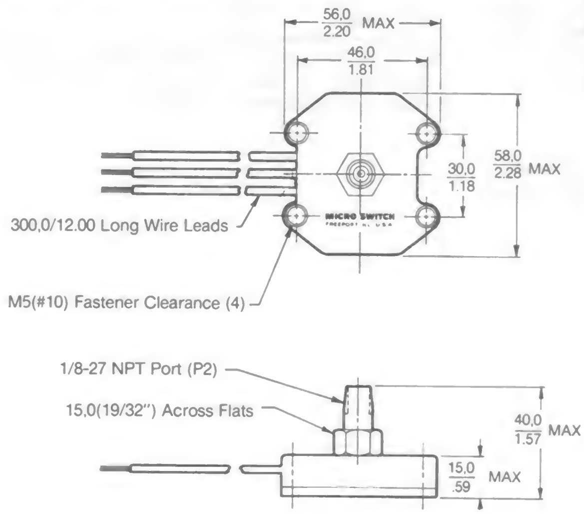


ELECTRICAL CONNECTIONS

Voltage Excitation



MOUNTING DIMENSIONS (For reference only)

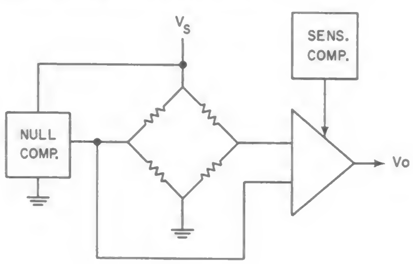


Leadwires
1 - Red, Vs
2 - Black, Ground (–)
3 - Green, Output

NOTES

1. Terminals are labeled on the sensor.
2. Input and output share a common ground.
3. R_L must be greater than or equal to 3000 ohms.

INTERNAL CIRCUITRY



Pressure Sensors
Pressure-to-Current/Amplified

FEATURES
- Unidirectional gage pressure measurement
- 2-wire, causes a 4-20 mA change in current, linearly proportional to pressure input
- Screw-in or flat-pack mounting
- Rugged die-cast aluminum housing

249PC SERIES PERFORMANCE CHARACTERISTICS at 24.0 ±0.01 VDC Excitation, 25 Ohm Load, 25°C

	Min.	Typ.	Max.	Units
Excitation	10.0	24.0	32.0	VDC
Response Time	---	---	1.00	msec
Supply Voltage Sensitivity 20-24 VDC and 24-28 VDC	---	±0.15	---	%Span
Stability over One Year	---	±1.0	---	%Span
Current Output				
249PC15G at 3 psig	3.7	4.0	4.3	mA
249PC15G at 15 psig	19.7	20.0	20.3	
Null (0-100 & 0-250 psig)	3.7	4.0	4.3	
Full pressure (0-100 & 0-250 psig)	19.5	20.0	20.5	
Weight	---	85	---	grams
Output Ripple	None, DC device			

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40° to +85°C (−40° to +185°F)
Storage Temperature	−40° to +85°C (−40° to +185°F)
Compensated Temperature	−18° to +63°C (0° to +145°F)
Shock	MIL-STD-202, Method 213 (50 g, half sine, 6 msec)
Vibration	MIL-STD-202, Method 204 (10 to 2000 Hz at 10 g)
Media	P2 port Wetted materials; die-cast aluminum housing, O-ring seal, silicon, borosilicate glass, and silicon-to-glass bond*

*Liquid media containing some highly ionic solutions could potentially neutralize the chip-to-glass tube bond.

249PC SERIES ORDER GUIDE, GAGE, Buna-N O-Ring Port Seal

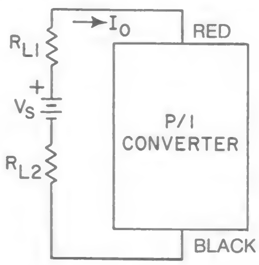
Catalog Listing	Pressure Range psi	Null & Sensitivity Shift 25 to 0°C, 25 to 50°C Max.	Sensitivity mA/psi	Overpressure psi %Span Max.	Linearity & Hysteresis %Span Max.	Repeatability B.F.S.L. Typ.
249PC15M*	3-15	±1.0	1.330	45	±0.75	±0.25
249PC100G	0-100	±1.0	0.160	200	±0.75	±0.25
249PC250G	0-250	±1.0	0.064	500	±1.00	±0.25

*Adhesive between thermoplastic and aluminum instead of O-ring seal.

249PC SERIES ORDER GUIDE, GAGE, Ethylene Propylene O-Ring Port Seal

Catalog Listing	Pressure Range psi	Null & Sensitivity Shift 25 to 0°C, 25 to 50°C Max.	Sensitivity mA/psi	Overpressure psi %Span Max.	Linearity & Hysteresis %Span Max.	Repeatability B.F.S.L. Typ.
249PC100GS	0-100	±1.0	0.160	200	±0.75	±0.25
249PC250GS	0-250	±1.0	0.064	500	±1.00	±0.25

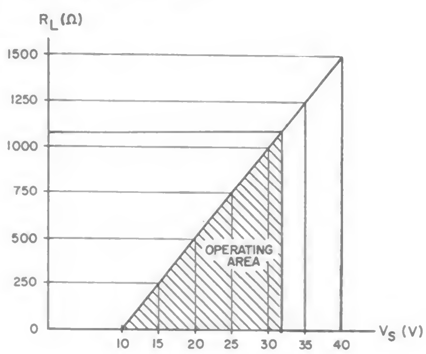
ELECTRICAL CONNECTION



NULL AND SENSITIVITY SHIFT

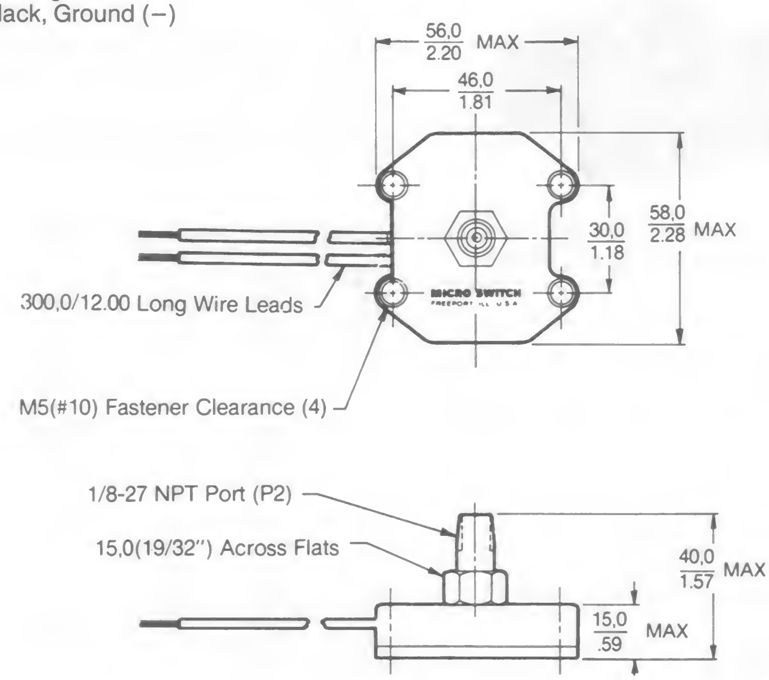
Current output pressure sensors are 100% tested to insure that the maximum null and sensivity temperature shift does not exceed the specification. The maximum shift occurs at temperature extremes. Therefore, if a sensor is not exposed to the entire temperature range, the maximum null and sensitivity shift will actually be less than the value specified.

EXTERNAL LOAD RESISTANCE VS SUPPLY VOLTAGE

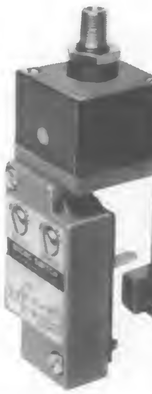


MOUNTING DIMENSIONS (For reference only)

Leadwires
1 – Red, V_S
2 – Black, Ground (–)



Pressure Sensors
Heavy Duty DC Adjustable, 2-Wire Analog



FEATURES
- Silicon sensor chip is enclosed in stainless steel welded diaphragm
- Rugged diecast zinc plug-in limit switch style housing
- 2-wire, 4-20 mA output current linearly proportional to pressure
- Sealed to meet NEMA 1, 3, 3R, 4, 6, 6P, 12, 13
- Field adjustable null and span
- Protected against false pulse, transients and industrial noise
- 0 to +50°C operating and compensated temperature
- UL Listed.

SSPB SERIES PERFORMANCE CHARACTERISTICS, 25°C

	Min.	Typ.	Max.	Units
Supply Voltage	12.0	---	36.0	VDC
Hysteresis & Repeatability @ nominal span @ max. span comp.	 --- ---	 --- ---	 ±0.5 ±1.5	 %Span
Temperature Error @ nom. span & max. comp.	---	±6.0	±10.0	%Span
Response Time	---	---	2.0	msec
Weight	414 grams (.91 lb.) Note: w/o receptacle			
Change in Current	4 to 20 mA proportional to pressure			
Null Pressure Setting (4 mA output)	Can be adjusted from 0 to 25% of full pressure range			
Full Pressure Setting (20 mA output)	Can be adjusted from 75 to 100% of full pressure range			

ENVIRONMENTAL SPECIFICATIONS

Storage Temperature	−25° to +85°C (−13° to +185°F)
Operating and Compensated Temperature	0° to 50°C (32° to 122°F)
Sealing	NEMA 1, 3, 3R, 4, 6, 6P, 12, 13*
Media	Limited only to those media which will not attack 316 stainless steel

***Application Note:** Enclosures are based, in general, on the broad definitions outlined in NEMA standards. Therefore, it will be necessary for the user to determine that a particular enclosure is adequate when exposed to the specific conditions that might exist in intended applications. Except as might otherwise be noted, all references to products relative to NEMA enclosure types are based on MICRO SWITCH evaluation only.

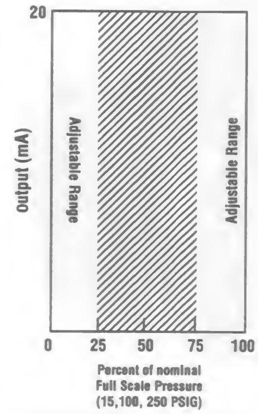
SSPB SERIES ORDER GUIDE, GAGE PRESSURE

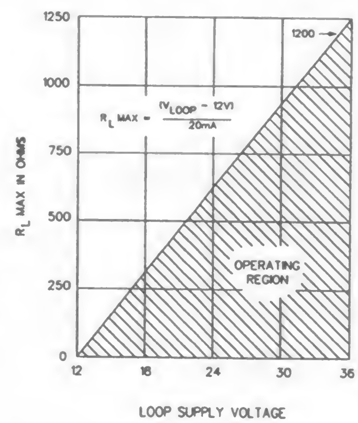
Catalog Listing	Nominal Pressure Range psig	Over Pressure Max. psi	Sensitivity (1) Range mA/psi
SSPB0015V	0-15	30	1.07 to 4.27
SSPB0100V	0-100	200	0.16 to 0.64
SSPB0250V	0-250	500	0.064 to 0.256

Mating Receptacle LSZ 4001

(1) NOTE: Sensitivity = $\frac{16 \text{ mA}}{\text{Upper Pressure Setting - Lower Pressure Setting}}$

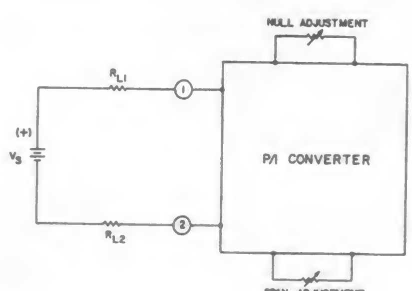
MAXIMUM EXTERNAL LOAD RESISTANCE VERSUS SUPPLY VOLTAGE



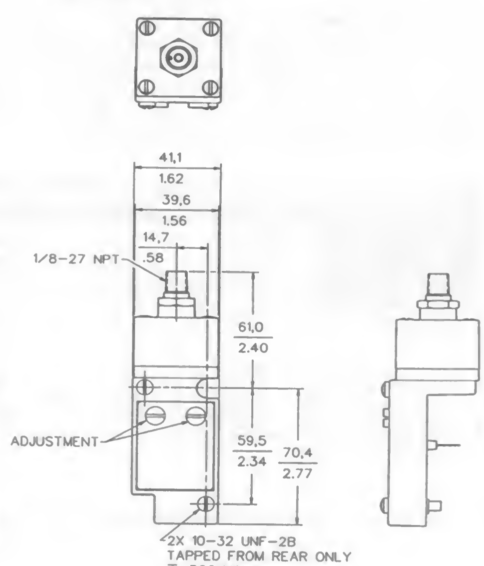


ELECTRICAL CONNECTIONS
An ammeter, resistor (current output generates a voltage drop across the resistor) or any current sensing device is placed in series with a DC voltage source and the pressure sensor for proper operation. The load, represented by R_L, can be placed on either or both sides of the voltage source. Total load resistance must be within operating area. Output and Power LEDs do not require separate wiring.

$$R_{L(max.)} = \frac{V_S - 12 \text{ volts}}{0.020 \text{ Amps}}$$



MOUNTING DIMENSIONS
(for reference only)

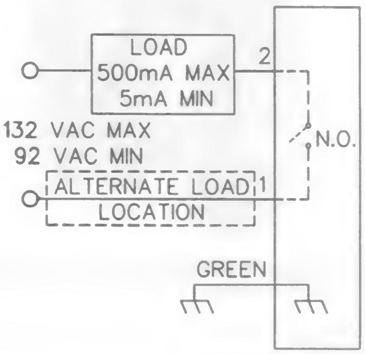


Pressure Sensors
Heavy Duty AC Adjustable Setpoint/2-Wire Digital

FEATURES
- Silicon sensor chip is enclosed in stainless steel welded diaphragm
- Rugged diecast zinc plug-in limit switch style housing
- Field adjustable setpoint and differential
- Sealed to meet NEMA 1, 3, 3R, 4, 6, 6P, 12, 13
- Protected against false pulse, transients, industrial noise and NEMA noise
- −25 to +85°C storage temperature
- 0 to +50°C operating and compensated temperature
- UL Listed

WIRING DIAGRAM

Output and Power LEDs do not require separate wiring.



WIRING DIAGRAM

SSPC SERIES PERFORMANCE CHARACTERISTICS, 25°C

	Min.	Typ.	Max.	Units
Supply Voltage	92.0	115	132	VAC
Repeatability @ 25°C Comp. temp. range	 --- ---	 --- ---	 ±0.5 ±3.0	 % of Adjustable range
Response Time Max (no time delay)	On - 20 msec		Off - 10 msec	
Rate of Operation	---	---	900	per minute
Power Dissipation	0.35 VA excluding load			
Saturation Voltage	9V max with 0.5 Amp load			
Load Current (N.O.)	0.5 Amp max. continuous over full temperature range 2.7 Amp. max. inrush			
Leakage Current (Off state)	2.0 mA RMS, max.			
Protection	False pulse, transients, Industrial noise, NEMA noise			
Weight	414 grams (.91 lb.) Note: w/o receptacle			

ENVIRONMENTAL SPECIFICATIONS

Storage Temperature	−25° to +85°C (−13° to 185°F)
Operating and Compensated Temperature	0° to 50°C (32° to 122°F)
Sealing	NEMA 1, 3, 3R, 4, 6, 6P, 12, 13*
Media	Limited only to those media which will not attack 316 stainless steel

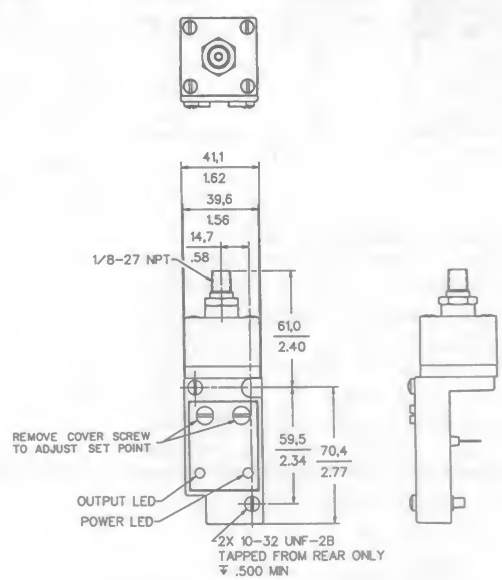
***Application Note:** Enclosures are based, in general, on the broad definitions outlined in NEMA standards. Therefore, it will be necessary for the user to determine that a particular enclosure is adequate when exposed to the specific conditions that might exist in intended applications. Except as might otherwise be noted, all references to products relative to NEMA enclosure types are based on MICRO SWITCH evaluation only.

SSPC SERIES ORDER GUIDE, GAGE PRESSURE

Catalog Listing	Nominal Pressure Range psig	Over-Pressure Max. psi	Adjustable Setpoint Range	Differential Min.
SSPC0015V	0-15	30	1.5-15	30% @ 1.5 psi, 10% @ F.S.
SSPC0100V	0-100	200	10-100	10%
SSPC0250V	0-250	500	25-250	10%

Mating Receptacle LSZ 4001

MOUNTING DIMENSIONS (for reference only)



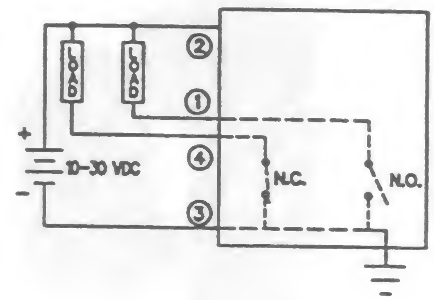
Pressure Sensors

Heavy Duty DC Adjustable Setpoint, 4-Wire Current Sinking

FEATURES

- Silicon sensor chip is enclosed in stainless steel welded diaphragm
- Rugged diecast zinc plug-in limit switch style housing
- Field Adjustable setpoint and differential
- Sealed to meet NEMA 1, 3, 3R, 4, 6, 6P, 12, 13
- Protected against false pulse, transients and industrial noise
- −25 to +85°C storage temperature
- 0 to +50° operating and compensated temperature
- UL Listed

WIRING DIAGRAM



SSPD SERIES PERFORMANCE CHARACTERISTICS, 25°C

Supply Voltage	10 to 30 VDC
Load Current (N.O. & N.C.)	200 mA Max (NPN)
Leakage current, N.C. state	10 µA Max
Voltage Drop, Max	1.25V with 200 mA load
Response Time, Max	15 Milliseconds
Protection	Power up protection, transients, industrial noise
Repeatability (Stability)	±0.5% of Set Points (@25°C) ±3.0% of Set Points (0°C to +50°C)

ENVIRONMENTAL SPECIFICATIONS

Storage Temperature	−25° to +85°C (−13° to 185°F)
Operating and Compensated Temperature	0° to 50°C (32° to 122°F)
Sealing	NEMA 1, 3, 3R, 4, 6, 6P, 12, 13*
Media	Limited only to those media which will not attack 316 stainless steel

***Application Note:** Enclosures are based, in general, on the broad definitions outlined in NEMA standards. Therefore, it will be necessary for the user to determine that a particular enclosure is adequate when exposed to the specific conditions that might exist in intended applications. Except as might otherwise be noted, all references to products relative to NEMA enclosure types are based on MICRO SWITCH evaluation only.

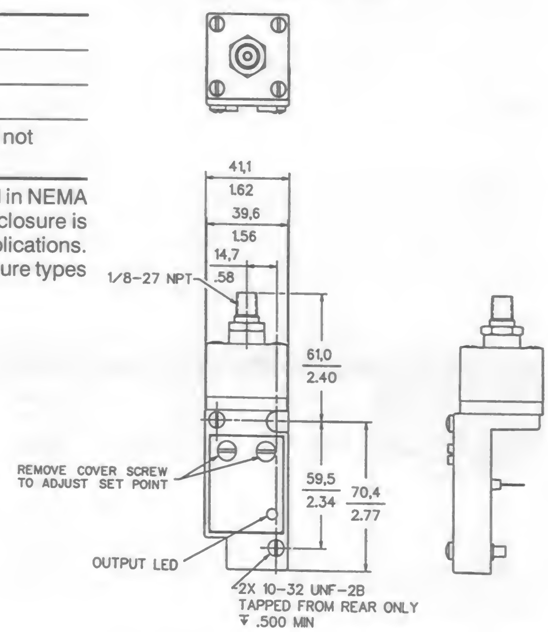
SSPD SERIES ORDER GUIDE, GAGE PRESSURE

Catalog Listing	Input Pressure Max. psig	Over-Pressure Max. psi	Adjustable Setpoint Range	Differential Min.
SSPD0015V	1.5-15	30	15	30% @ 1.5 psi. 10% @ F.S.
SSPD0100V	100	200	10-100	10%
SSPD0250V	250	500	25-250	10%

Mating Receptacle LSZ 4001

SSPD Series has one bicolor Output LED.

MOUNTING DIMENSIONS
(for reference only)



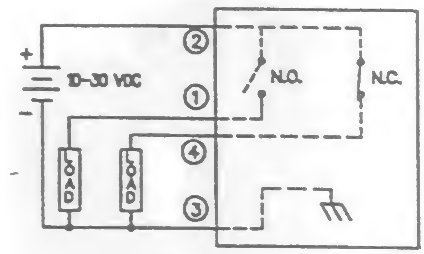
Pressure Sensors

Heavy Duty DC Adjustable Setpoint, 4-Wire Current Sourcing

FEATURES

- Silicon sensor chip is enclosed in stainless steel welded diaphragm
- Rugged diecast zinc plug-in limit switch style housing
- Field Adjustable setpoint and differential
- Sealed to meet NEMA 1, 3, 3R, 4, 6, 6P, 12, 13
- Protected against false pulse, transients and industrial noise
- −25 to +85°C storage temperature
- 0 to +50° operating and compensated temperature
- UL Listed

WIRING DIAGRAM



SSPE SERIES PERFORMANCE CHARACTERISTICS, 25°C

Supply Voltage	10 to 30 VDC
Load Current (N.O. & N.C.)	200 mA Max (sourcing)
Leakage current, N.C. state	10 μA Max
Voltage Drop, Max	1.25V with 200 mA load
Response Time, Max	15 Milliseconds
Protection	Power up protection, transients, industrial noise
Repeatability (Stability)	±0.5% of Set Points (@25°C) ±3.0% of Set Points (0°C to +50°C)

ENVIRONMENTAL SPECIFICATIONS

Storage Temperature	−25° to +85°C (−13° to 185°F)
Operating and Compensated Temperature	0° to 50°C (32° to 122°F)
Sealing	NEMA 1, 3, 3R, 4, 6, 6P, 12, 13*
Media	Limited only to those media which will not attack 316 stainless steel

***Application Note:** Enclosures are based, in general, on the broad definitions outlined in NEMA standards. Therefore, it will be necessary for the user to determine that a particular enclosure is adequate when exposed to the specific conditions that might exist in intended applications. Except as might otherwise be noted, all references to products relative to NEMA enclosure types are based on MICRO SWITCH evaluation only.

SSPE SERIES ORDER GUIDE, GAGE PRESSURE

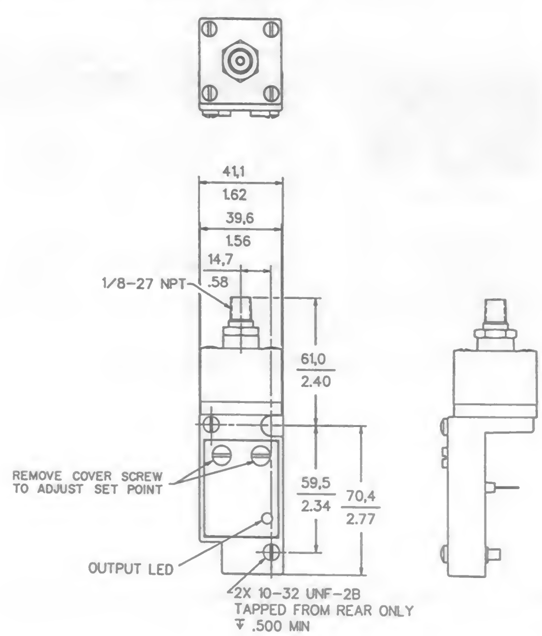
Catalog Listing	Input Pressure Max. psig	Over-Pressure Max. psi	Adjustable Setpoint Range	Differential Min.
SSPE0015V	15	30	1.5-15	30% @ 1.5 psi, 10% @ F.S.
SSPE0100V	100	200	10-100	10%
SSPE0250V	250	500	25-250	10%

Mating Receptacle LSZ 4001

SSPE Series has one bicolor Output LED

MOUNTING DIMENSIONS

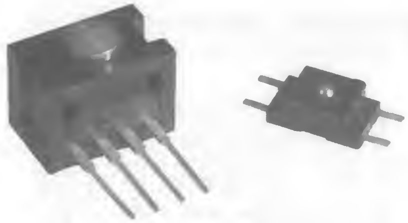
(for reference only)



Force Sensors

FSG and FSL Series

NEW



FEATURES

- Compact commercial grade package
- Robust performance characteristics
- Adaptable product design
- Precision force sensing
- Electrically ratiometric output
- Extremely low deflection (30 microns typ. @ Full Scale)
- High ESD resistance 10 KV
- Available signal conditioning
- Optional terminal configurations

The FS Series Force Sensors provide precise, reliable force sensing performance in a compact commercial grade package. The sensor features a proven sensing technology that utilizes a specialized piezoresistive micro-machined silicon sensing element. The low power, unamplified, noncompensated Wheatstone bridge circuit design provides inherently stable mV outputs over the force range.

Force sensors operate on the principle that the resistance of silicon implanted piezoresistors will increase when the resistors flex under any applied force. The sensor concentrates force from the application, through the stainless steel plunger, directly to the silicon sensing element. The amount of resistance changes in proportion to the amount of force being applied. This change in circuit resistance results in a corresponding mV output level.

The sensor package design incorporates a patented modular construction. The use of innovative elastomeric technology and engineered molded plastics results in load capacities of 4.5 Kg over-force. The stainless steel plunger provides excellent mechanical stability and is adaptable to a variety of applications. Various electrical interconnects can accept prewired connectors, printed circuit board mounting, and surface mounting. The unique sensor design also provides a variety of mounting options including mounting brackets, as well as application specific mounting requirements.

MOUNTING

Sensor output characteristics do not change with respect to mounting orientation. Care should be taken not to obstruct the vent hole in the bottom of the housing. Improper venting may result in unstable output.

APPLYING FORCE

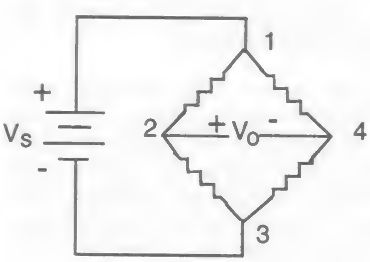
Evaluation of the sensor is to be performed using deadweight or compliant force. Application of a rigid, immobile force will result in output drift (decrease) as elastomeric seals relax. Off-center plunger loading has minimal effect on sensor performance and maintains operation within design specifications.

TYPICAL APPLICATIONS

1. Medical infusion pumps
2. Kidney dialysis machines
3. Load and compression sensing
4. Variable tension control
5. Robotic end-effectors
6. Wire bonder equipment

Force

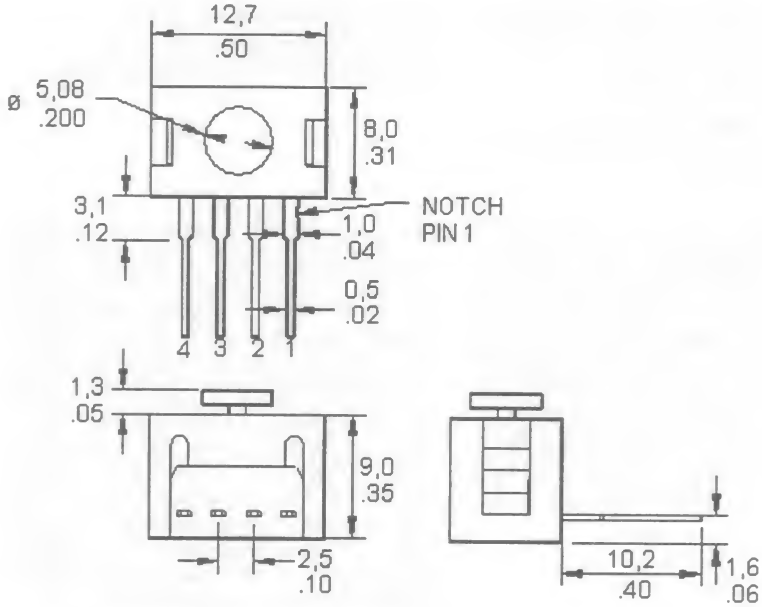
ELECTRICAL CONNECTIONS



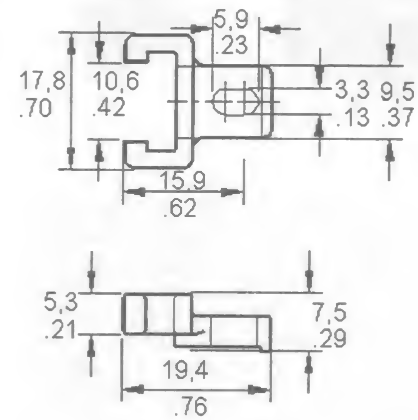
FS SERIES CIRCUIT NOTES

1. Circled numbers refer to Sensor Terminals (interface pins).
   Pin 1 = V_s (+)
   Pin 2 = Output, (+)
   Pin 3 = Ground, (−)
   Pin 4 = Output, (−)
2. The force sensor may be powered by voltage or current. Maximum supply voltage is not to exceed 12 volts. Maximum supply current is not to exceed 1.6 mA. Power is applied across Pin 1 and Pin 3.
3. The sensor output should be measured as a differential voltage across Pin 2 and Pin 4 ($V_o = V_2 - V_4$). The output is ratiometric to the supply voltage. Shifts in supply voltage will cause shifts in output. Neither Pin 2 nor Pin 4 should be tied to ground or voltage supply.

MOUNTING DIMENSIONS (for reference only)
FSG15N1A



ACCESSORY (FSG Sensor only)
PC-15132 Plastic Mounting Bracket



PERFORMANCE CHARACTERISTICS @ 10.0 ±0.01 VDC, 25°C

Parameter	Min.	Typ.	Max.	Units
Excitation*	—	10.0	12.0	VDC
Null offset	−30	0	30	mV
Operating Force	0	—	1500	grams
Sensitivity	0.20	0.24	0.28	mV/gram
Linearity (B.F.S.L.)**	—	±22.5	45	grams
Null Shift +25°C to 0°C, +25°C to +50°C	—	±1.0	—	mV
Sensitivity Shift +25°C to 0°C	—	0.012	—	mV/gram
+25°C to +50°C	—	−0.012	—	mV/gram
Hysteresis	—	45	180	grams
Repeatability (@ 1500 grams)	—	30	120	grams
Input Resistance	4.0 K	5.0 K	6.0 K	Ohms
Output Resistance	4.0 K	5.0 K	6.0 K	Ohms
Overforce	—	—	4,500	grams

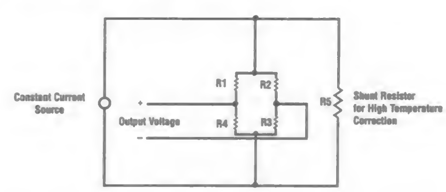
ENVIRONMENTAL SPECIFICATIONS

Operating Temperature	−40° to 85°C (−40° to +185°F)
Storage Temperature	−55° to +105°C (−131° to +221°F)
Vibration	Qualification tested to 10 Hz to 2 kHz, 20 g sine
Shock	Qualification tested to 150 g, 6 ms, half-sine
Solderability	5 sec at 315°C per lead
Output ratiometric	Within Supply Range

**B.F.S.L.—Best Fit Straight Line
Note: All force related specifications established using dead weight or compliant force.

Constant Current Excitation Schematic
*Non-compensated force sensors, excited by constant current instead of voltage, exhibit temperature compensation of Span. Application Note #1 briefly discusses current excitation.

Constant current excitation has an additional benefit of temperature measurement. When driven by a constant current source, a silicon pressure sensor's terminal voltage will rise with increased temperature. The rise in voltage not only compensates the Span, but is also an indication of die temperature.



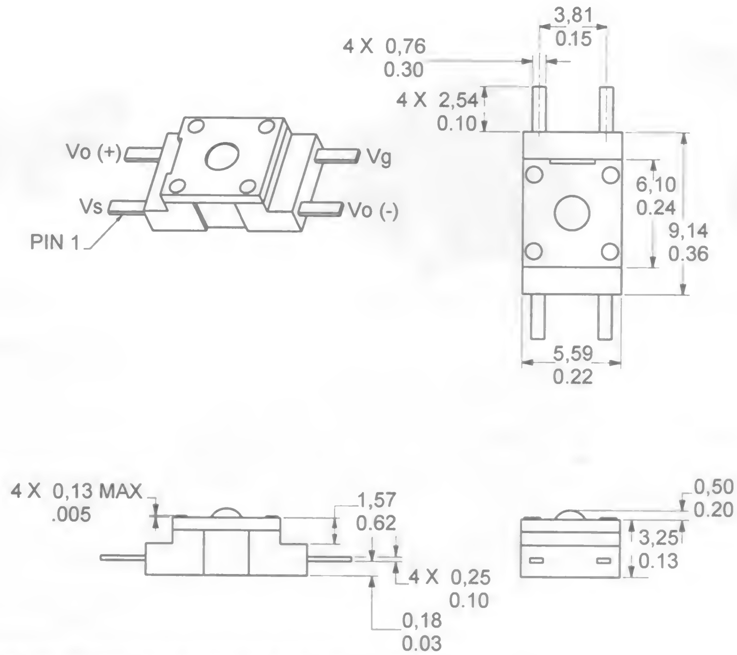
FS SERIES ORDER GUIDE

Catalog Listing	Force Range (grams)	Sensitivity mV/V/gram			Span mV	Over Force grams
		Min.	Typ.	Max.	Typ.	Max.
FSG15N1A	1,500	.02	.024	.028	360 (at 10 VDC)	4,500

Force Sensors
FSG and FSL Series

NEW

MOUNTING DIMENSIONS (for reference only)
FSL05N2C



PERFORMANCE CHARACTERISTICS @ 5.0 ±0.01 Excitation, 25°C

Parameter	Min.	Typ.	Max.	Units
Excitation*	—	5.0	12	VDC
Null offset	−15	0	15	mV
Operating Force	0	—	500	grams
Sensitivity	0.1	0.12	0.14	mV/gram
Linearity (B.F.S.L.)**	—	±10	—	grams
Repeatability @ 300 g	—	±10	—	grams
Null Shift +25°C to 2°C, +25°C to +40°C	—	±0.5	—	mV
Sensitivity Shift +25°C to 2°C	—	0.012	—	mV/gram
+25°C to +40°C	—	−0.012	—	mV/gram
Input Resistance	4.0 K	5.0 K	6.0 K	Ohms
Output Resistance	4.0 K	5.0 K	6.0 K	Ohms
Overforce	—	—	4,500	grams
ESD (Direct contact, terminals and plunger)	10	—	—	kVolts

ENVIRONMENTAL SPECIFICATIONS

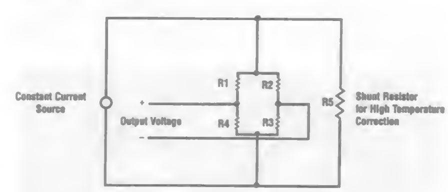
Operating Temperature	+2°C to +40°C (+36°F to +104°F)
Storage Temperature	−40° to +70°C (−40° to +158°F)
Vibration	Qualification tested to 10 Hz to 2 kHz, 20 g sine
Shock	Qualification tested to 150 g, 6 ms, half-sine
MCTF	7 million
Solderability	5 sec at 315°C per lead
Output ratiometric	Within Supply Range

**B.F.S.L.—Best Fit Straight Line
Note: All force related specifications established using dead weight or compliant force.

Constant Current Excitation Schematic

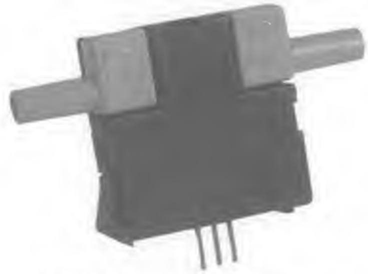
*Non-compensated force sensors, excited by constant current instead of voltage, exhibit temperature compensation of Span. Application Note #1 briefly discusses current excitation.

Constant current excitation has an additional benefit of temperature measurement. When driven by a constant current source, a silicon pressure sensor's terminal voltage will rise with increased temperature. The rise in voltage not only compensates the Span, but is also an indication of die temperature.



FS SERIES ORDER GUIDE

Catalog Listing	Force Range (grams)	Sensitivity mV/V/gram Min.	Sensitivity mV/V/gram Typ.	Sensitivity mV/V/gram Max.	Span mV Typ.	Over Force grams Max.
FSL05N2C	500	.02	.024	.028	60 (at 5 VDC)	4,500



AWM 1000/2000/3000 Series

AWM 40000 Series

AWM 5000 Series

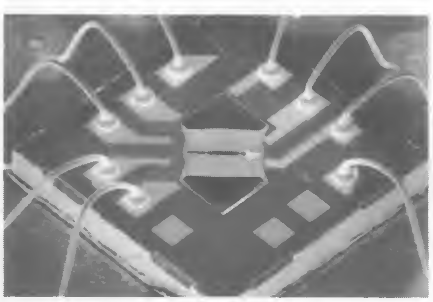
FEATURES
- State-of-the-art silicon micromachining
- Sensitive to low flows – 0.1 sccm to 20 SLPM
- Adaptable for use with higher flows (See Application Note 2 page 128.)
- Fast response time
- Analog output
- Low power consumption
- Repeatable response
- Laser-trimmed interchangeability
- Accurate, cost effective flow sensing
- In-line printed circuit board terminals
- Standard 0.100″ (2,54mm) mounting centers
- Accurate sensing of low pressure 0.001″ to 4.0″ H_2O (.003 to 10mBar)

APPLICATIONS
- Damper control for heating, ventilation, and air conditioning systems
- Gas analyzers
- Low vacuum control
- Process control
- Medical respirators and ventilators
- Oxygen concentrators
- Leak detection equipment
- Vent hoods
- Anesthesia control
- Gas metering
- Gas chromatography

OPERATION

The microbridge mass airflow sensor operates on the theory of heat transfer. Mass airflow is directed across the surface of the sensing elements. Output voltage varies in proportion to the mass air or other gas flow through the inlet and outlet ports of the package. The specially designed housing precisely directs and controls the airflow across the microstructure sense element. Mechanical design of the package allows it to be easily mounted to printed circuit boards.

The microbridge mass airflow sensor has a unique silicon chip based on advanced microstructure technology. It consists of a thin-film, thermally isolated bridge structure containing heater and temperature sensing elements. The bridge structure provides a sensitive and fast response to the flow of air or other gas over the chip. Dual sensing elements positioned on both sides of a central heating element indicate flow direction as well as flow rate. Laser trimmed thick film and thin film resistors provide consistent interchangeability from one device to the next.



The microbridge mass airflow sensor uses temperature-sensitive resistors deposited within a thin film of silicon nitride. They are suspended in the form of two bridges over an etched cavity in the silicon, shown below. The chip is located in a precisely dimensioned airflow channel to provide a repeatable flow response. Highly effective thermal isolation for the heater and sensing resistors is attained by etching the cavity space beneath the flow sensor bridges. The small size and thermal isolation of the microbridge mass airflow sensor are responsible for the extremely fast response and high sensitivity to flows.

Dual Wheatstone bridges control airflow measurement — one provides closed loop heater control, the other contains the dual sensing elements. The heater circuit minimizes shift due to ambient temperature changes by providing an output proportional to mass flow. The circuit keeps the heater temperature at a constant differential (160°C) above ambient air temperature which is sensed by a heat-sunk resistor on the chip. The ratiometric voltage output of the device corresponds to the differential voltage across the Wheatstone bridge circuit.

NOTICE

Dust contamination may be possible in some applications, the effects of which can be minimized. By design, dust particles that may be present in the air stream will flow past the chip parallel to the chip surface. In addition, the microstructure chip produces a thermophoretic effect, which repels micrometer-sized dust particles away from the bridge structure.

Dust adherence to chip edges and channel surfaces can be prevented using a simple filter. A disposable five-micron filter used in series on the upstream side of the airflow device will provide adequate filtering in most applications. For a list of possible filter sources, see Filter Manufacturers, page 126.

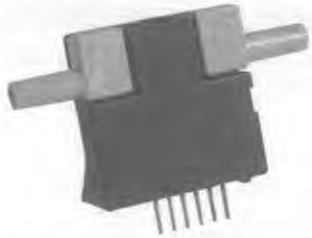
CAUTION

PRODUCT DAMAGE

AWM Series Microbridge Mass Airflow Sensors are **NOT** designed to sense liquid flow and will be damaged by liquid flow through the sensor.

Airflow Sensors

Microbridge Mass Airflow/Unamplified



FEATURES

- Cost-effective microbridge technology
- Accurate, repeatable airflow sensing
- Bi-directional sensing capability
- Low differential pressure sensing

Take advantage of microbridge mass flow sensor technology. The AWM1000 series mass flow sensor provides all of the outstanding performance benefits of the standard AWM2000 series in a more cost-effective sensor platform. This device provides accurate, repeatable flow sensing. Sensor to sensor interchangeability specifications are approximately twice as large as compared to the AWM2000 series.

The heater control circuit in Figure 1 and the sensing bridge supply circuit in Figure 2 are both required for operation per specification. These two circuits are **NOT** on board the sensor and must be supplied in the application. The differential amplifier circuitry in Figure 3 may be useful in providing output gain and/or introducing voltage offsets to the sensor output (Ref. Equation 1).

NOTE: For applications involving sensing hydrogen (H_2) gas or helium (He) gas, see Application Note 3, page 131.

Figure 1
Heater Control Circuit

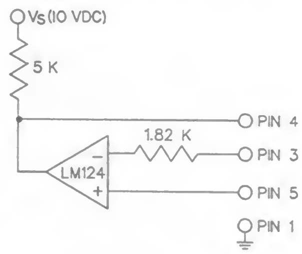


Figure 2
Sensing Bridge Supply Circuit

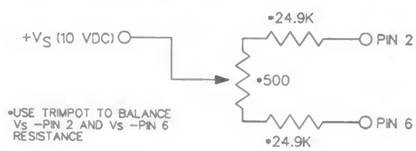
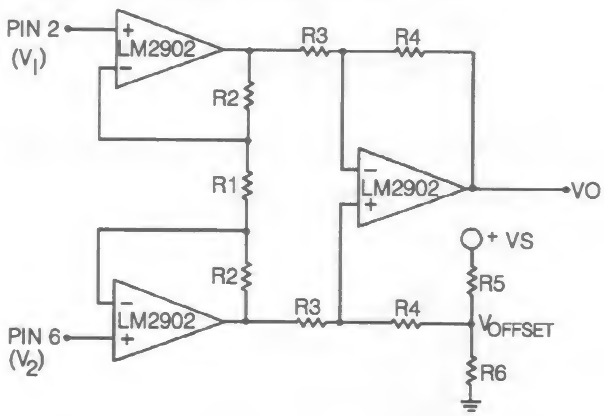


Figure 3
Differential Instrumentation Amplifier Circuit



Equation 1:

$$V_o = \left(\frac{2R_2+R_1}{R_1}\right)\left(\frac{R_4}{R_3}\right)\left(V_2-V_1\right) + V\ \text{offset}$$

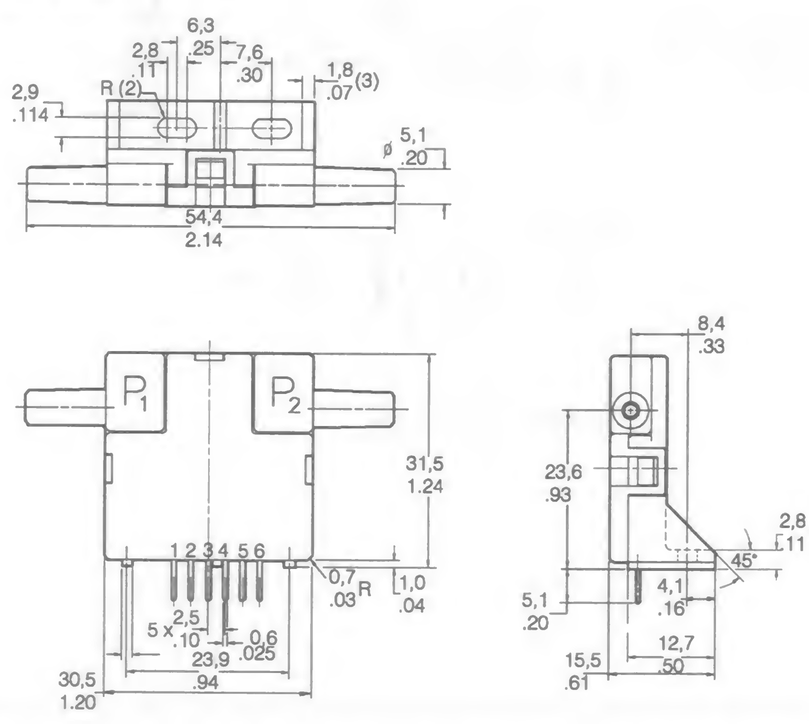
$$\text{where } V\ \text{offset} = V_S\left(\frac{R_6}{R_6+R_5}\right)$$

AWM1000 SERIES ORDER GUIDE (Performance Characteristics @ 10.0 ±0.01 VDC, 25°C)

Catalog Listings	AWM1100V	AWM1200V	AWM1300V
Flow Range (Full Scale)	±200 sccm		+1000 sccm to −600 sccm
Pressure Range (See Application Note #1)		±4.0″ H_2O (10 mBar)	
Output Voltage @ Trim Point	30 mV @ 100 sccm	20 mV @ 2.0″ H_2O	50 mV @ 650 sccm
Null Voltage Shift, Typ. +25 to −25°C, +25 to 85°C	±0.7 mV (max.)	±0.7 mV (max.)	±0.7 mV (max.)
Output Voltage Shift, Max. +25 to −25°C +25 to +85°C	±4% Full Scale ±4% Full Scale	+22% Reading (Note 2) −22% Reading	±4% Full Scale ±4% Full Scale
Repeatability & Hysteresis, Max.	±1% Full Scale	±1% Full Scale	±1% Full Scale
	Min.	**Typ.**	**Max.**
Excitation (VDC) (Note 1)	8.0	10±0.01	15
Power Consumption (mW)	—	30	50
Null Voltage (mV)	−1.0	0.0	+1.0
Response Time (msec)	—	1.0	3.0
Common Mode Pressure (psi)	—	—	25
Sensor Resistance (kΩ) Pin 2-Pin 1, Pin 6-Pin 1	—	5	—
Sensor Current (mA) Pin 2-Pin 1, Pin 6-Pin 1	—	0.3	0.6
Temperature Range	Operating: −25° to +85°C (−13° to +185°F); Storage: −40° to +90°C (−40° to +194°F)		
Termination	2,54 mm (.100″) centers, 0,635 mm (0.025″) square		
Weight (grams)	10.8		
Shock Rating	100 g peak (5 drops, 6 axes)		

Notes:
1. Output Voltage is ratiometric to supply voltage.
2. Temperature shifts when sensing differential pressure correlates to the density change of the gas over temperature. See Application Note 1.
3. Maximum allowable rate of flow change to prevent damage: 5 SLPM/1.0 sec.

MOUNTING DIMENSIONS (for reference only)



NOTE: Positive flow direction is defined as proceeding from Port 1 (P1) to Port 2 (P2) and results in positive output (Pin 6 > Pin 2). Negative flow direction is defined conversely and results in negative output (Pin 6 < Pin 2). Do not exert a force greater than 4.54 kg (10 lbs.) in any direction.

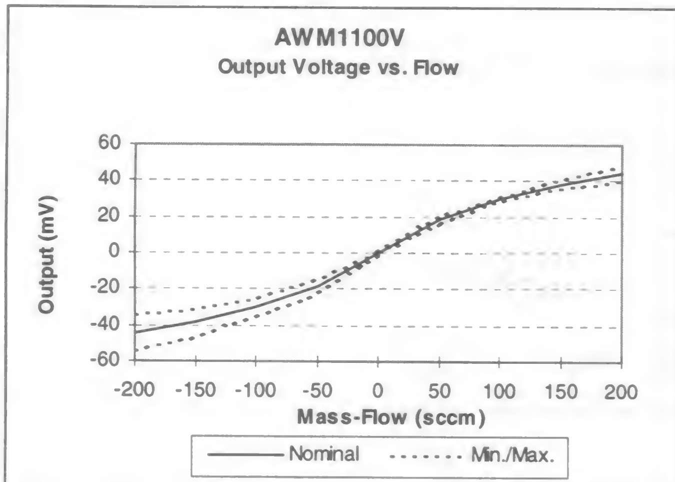
Airflow Sensors
Microbridge Mass Airflow/Unamplified

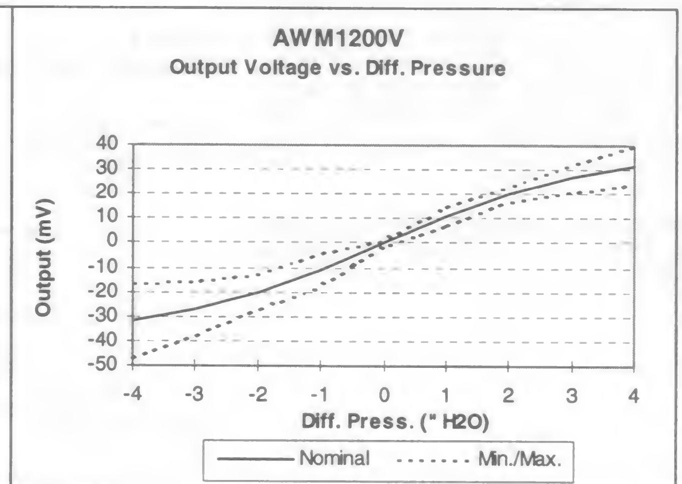
OUTPUT FLOW VS INTERCHANGEABILITY (Note 1) Performance Characteristics @ 10.0 ±0.01 VDC, 25°C

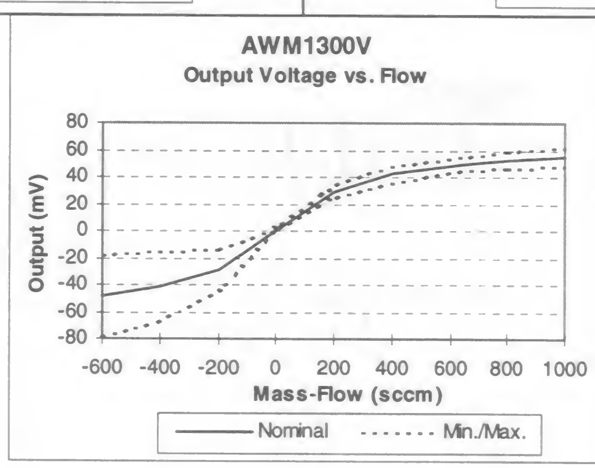
AWM1100V				AWM1200V (Note 2)				AWM1300V			
Press mBar	**Flow sccm**	Nom. mV	Tol. ±mV	Flow sccm	**Press. " H_2O**	Nom. mV	Tol. ±mV	Press mBar	**Flow sccm**	Nom. mV	Tol. ±mV
0.49	**200**	44.25	4.25	120	**4.00**	31.75	8.0	3.4	**1000**	55.50	7.0
0.35	**150**	38.75	3.00	90	**3.00**	26.75	6.0	2.4	**800**	52.90	6.0
0.21	**100**	30.00	1.00	60	**2.00**	20.00	3.0	1.8	**650**	50.00	5.0
0.09	**50**	18.40	2.00	30	**1.00**	11.20	4.0	0.83	**400**	42.50	6.0
0	**0**	0.00	1.00	0	**0.00**	0.00	1.0	0.31	**200**	29.20	5.0
−0.09	**−50**	−18.40	3.90	−30	**−1.00**	−11.20	7.0	0	**0**	0.00	1.5
−0.21	**−100**	−30.00	5.00	−60	**−2.00**	−20.00	7.0	−0.31	**−200**	−28.90	15.0
−0.35	**−150**	−38.75	7.65	−90	**−3.00**	−26.75	11.0	−0.83	**−400**	−41.20	26.0
−0.49	**−200**	−44.25	9.75	−120	**−4.00**	−31.75	15.0	−1.6	**−600**	−48.20	30.0

Notes:
1. Numbers in **BOLD** type indicate calibration type, mass flow or differential pressure. Tolerance values apply to calibration type only.
2. Differential pressure calibrated devices are not recommended for flow measurement. Use flow calibrated devices for flow measurement.

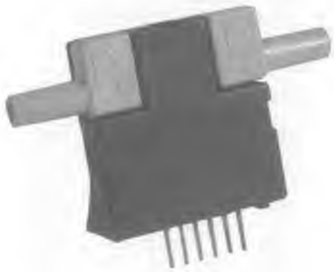
OUTPUT CURVES







Airflow Sensors
Microbridge Mass Airflow/Unamplified



FEATURES
- Bidirectional sensing capability
- Actual mass air flow sensing
- Low differential pressure sensing

The AWM2000 Series microbridge mass airflow sensor is a passive device comprised of two Wheatstone bridges. The heater control circuit in Figure 1 is required for operation per specifications. The sensing bridge supply circuit in Figure 2 is also required for operation per specifications. These two circuits are **not on board** the package and must be supplied in the application. The differential amplifier in Figure 3 is a useful interface for the sensing bridge. It can be used to introduce the gain and to introduce voltage offsets to the sensor output as referenced in Equation 1.

Note: For applications sensing hydrogen or helium, see Application Note 3, page 131.

Figure 1
Heater Control Circuit

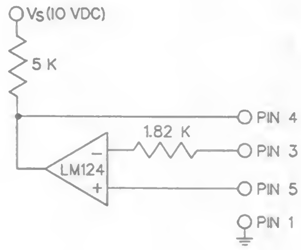


Figure 2
Sensing Bridge Supply Circuit

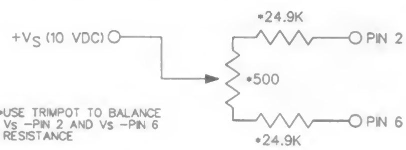
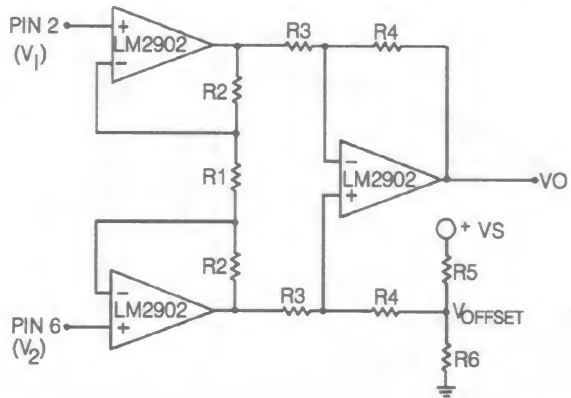


Figure 3
Differential Instrumentation Amplifier Circuit



Equation 1:

$$V_o = \left(\frac{2R_2+R_1}{R_1}\right)\left(\frac{R_4}{R_3}\right)\left(V_2-V_1\right) + V\text{ offset}$$

$$\text{where } V\text{ offset} = V_s\left(\frac{R_6}{R_6+R_5}\right)$$

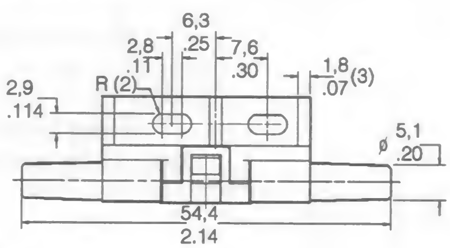
Airflow Sensors
Microbridge Mass Airflow/Unamplified

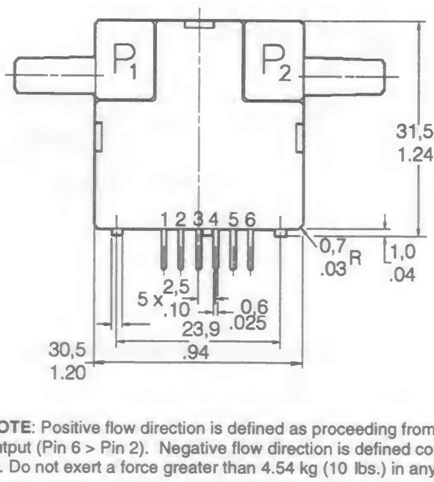
AWM2000 SERIES ORDER GUIDE (Performance Characteristics @ 10.01 ±0.01 VDC, 25°C)

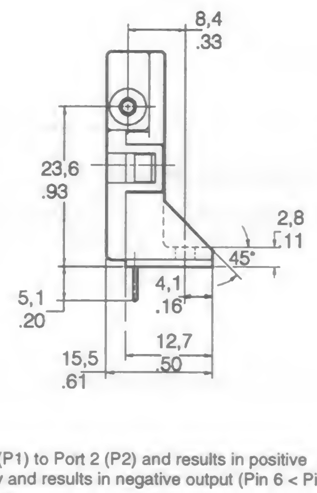
Catalog Listings	AWM2100V	AWM2150V	AWM2200V	AWM2300V
Flow Range (Full Scale)	±200 sccm	±30 sccm		±1000 sccm
Pressure Range (See Application Note #1)			±4.0″ H_2O (10 mBar)	
Output Voltage @ Trim Point	30 mV @ 100 sccm	11.8 mV @ 25 sccm	20 mV @ 2″ H_2O	50 mV @ 650 sccm
Null Voltage Shift, Typ. +25° to −25°C, +25° to 85°C	±0.20 mV	±0.20 mV	±0.20 mV	±0.20 mV
Output Voltage Shift, Max. +25° to −25°C / +25° to +85°C	+2.5% Reading / −2.5% Reading	+5% Reading / −5% Reading	+22% Reading (Note 2) / −22% Reading	+5% Reading / −5% Reading
Repeatability & Hysteresis, Max.	±0.35% Reading	±0.35% Reading	±0.35% Reading	±1% Reading
	Min.	**Typ.**	**Max.**	
Excitation (VDC) (Note 1)	8.0	10±0.01	15	
Power Consumption (mW)	—	30	50	
Null Voltage (mV)	−1.0	0.0	+1.0	
Response Time (msec)	—	1.0	3.0	
Common Mode Pressure (psi)	—	—	25	
Sensor Resistance (kΩ) Pin 2-Pin 1, Pin 6-Pin 1	—	5	—	
Sensor Current (mA) Pin 2-Pin 1, Pin 6-Pin 1	—	—	0.6	
Temperature Range	Operating: −25° to +85°C (−13° to +185°F); Storage: −40° to +90°C (−40° to +194°F)			
Termination	2,54 mm (.100″) centers, 0,635 mm (0.025″) square			
Weight (grams)	10.8			
Shock Rating	100 g peak (5 drops, 6 axes)			

Notes:
1. Output Voltage is ratiometric to supply voltage.
2. Temperature shifts when sensing differential pressure correlates to the density change of the gas over temperature. See Application Note 1.
3. Maximum allowable rate of flow change to prevent damage: 5.0 SLPM/1.0 sec.

MOUNTING DIMENSIONS (for reference only)







NOTE: Positive flow direction is defined as proceeding from Port 1 (P1) to Port 2 (P2) and results in positive output (Pin 6 > Pin 2). Negative flow direction is defined conversely and results in negative output (Pin 6 < Pin 2). Do not exert a force greater than 4.54 kg (10 lbs.) in any direction.

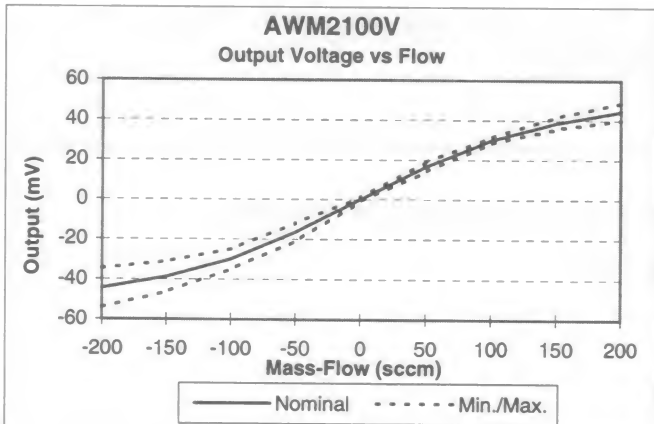
Airflow Sensors
Microbridge Mass Airflow/Unamplified

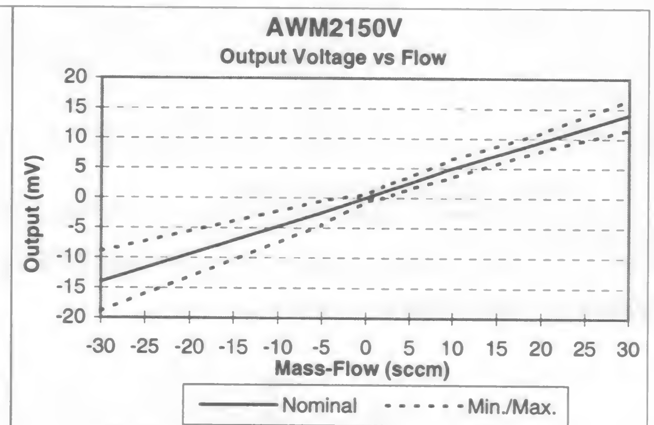
OUTPUT FLOW VS INTERCHANGEABILITY (Note 1) **Performance Characteristics @ 10.0 ±0.01 VDC, 25°C**

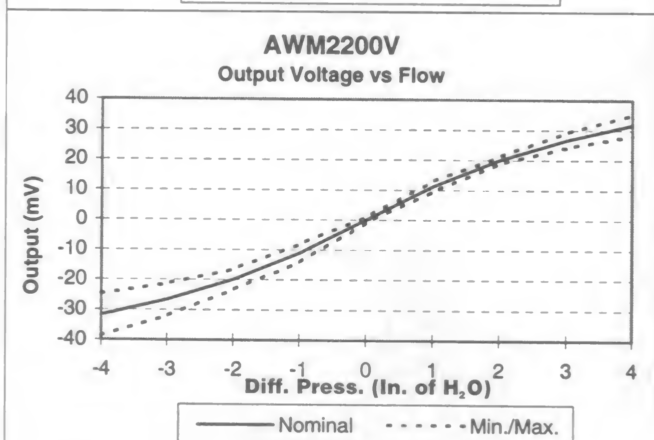
AWM2100V				AWM2150V				AWM2200V (Note 2)				AWM2300V			
Press. mBar	**Flow sccm**	**Nom. mV**	**Tol. ±mV**	Press. μBar	**Flow sccm**	**Nom. mV**	**Tol. ±mV**	Flow sccm	**Press. ″ H_2O**	**Nom. mV**	**Tol. ±mV**	Press. mBar	**Flow sccm**	**Nom. mV**	**Tol. ±mV**
0.49	**200**	44.50	4.25	53	**30**	14.0	2.5	120	**4.00**	31.75	3.50	3.4	**1000**	55.50	3.70
0.35	**150**	38.75	3.00	36	**20**	9.5	1.5	90	**3.00**	26.75	2.50	2.4	**800**	52.90	3.50
0.21	**100**	30.00	1.50	17	**10**	5.0	1.5	60	**2.00**	20.00	1.20	1.8	**650**	50.00	2.50
0.09	**50**	16.50	2.50	9.8	**5**	2.5	1.0	30	**1.00**	11.20	1.80	0.83	**400**	42.50	3.00
0.00	**0**	0.00	1.00	7.4	**4**	2.0	1.0	0	**0.00**	0.00	1.00	0.31	**200**	29.20	3.20
−0.09	**−50**	−16.50	4.50	6.2	**3**	1.5	1.0	−30	**−1.00**	−11.20	3.00	0	**0**	0.00	1.00
−0.21	**−100**	−30.00	5.00	5	**2**	1.0	1.0	−60	**−2.00**	−20.00	3.30	−0.31	**−200**	−28.90	15.00
−0.35	**−150**	−38.80	7.65	2.5	**1**	0.5	0.8	−90	**−3.00**	−26.75	5.30	−0.83	**−400**	−41.20	26.00
−0.49	**−200**	−44.50	9.75	0	**0**	0.0	0.6	−120	**−4.00**	−31.75	7.00	−1.6	**−600**	−48.20	29.50
				−9.8	**−5**	−2.5	2.0					−2.4	**−800**	−52.20	32.50
				−53	**−30**	−14.0	5.0					−3.4	**−1000**	−55.00	36.00

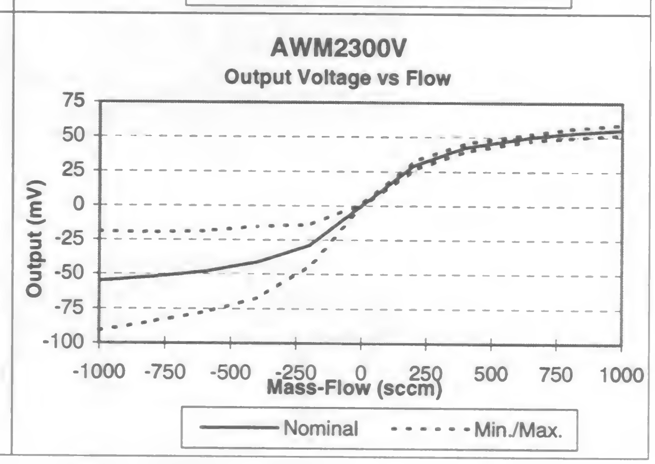
Notes:
1. Numbers in **BOLD** type indicate calibration type, mass flow or differential pressure. Tolerance values apply to calibration type only.
2. Differential pressure calibrated devices are not recommended for flow measurement. Use flow calibrated devices for flow measurement.

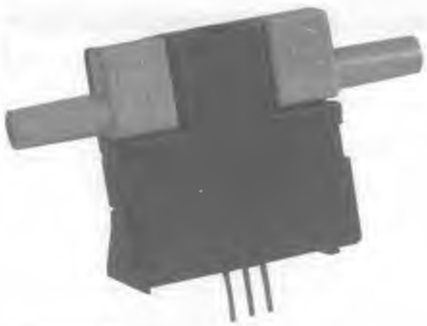
OUTPUT CURVES











FEATURES

- Laser trimmed for improved sensor interchangeability
- Flow sensing up to 1.0 SLPM
- Low differential pressure sensing

Like the AWM2000 Series, the dual Wheatstone bridges control airflow measurement. The AWM3000 Series is amplified; therefore, it can be used to increase the gain and to introduce voltage offsets to the sensor output. The schematic in Figure 3 depicts the amplification circuitry on board the sensor. Also, the heater control circuit (see Figure 1) and the sensing bridge supply circuit (see Figure 2) are on board the package.

Figure 1
Heater control circuit

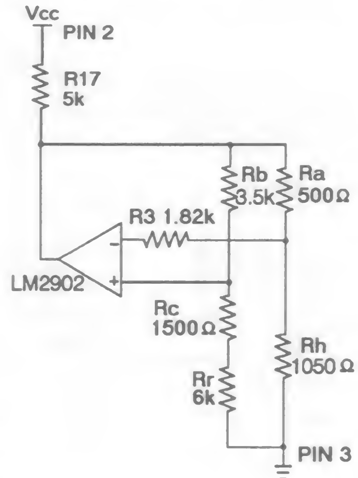


Figure 2
Sensing bridge supply circuit

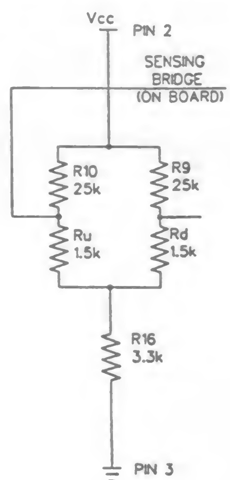
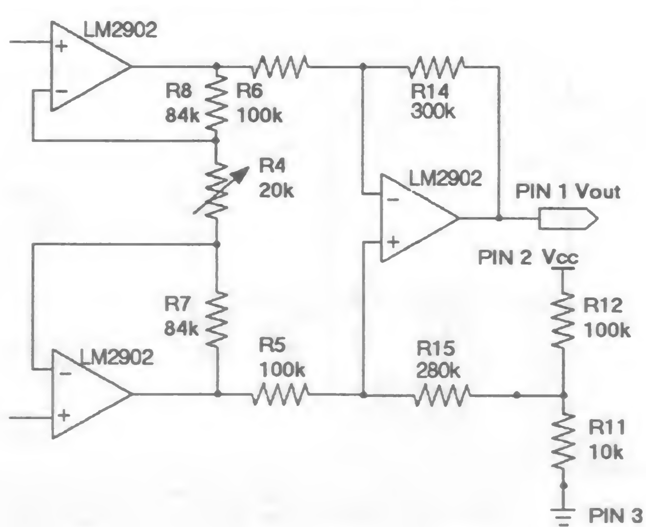


Figure 3
Differential instrumentation amplifier circuit



Airflow

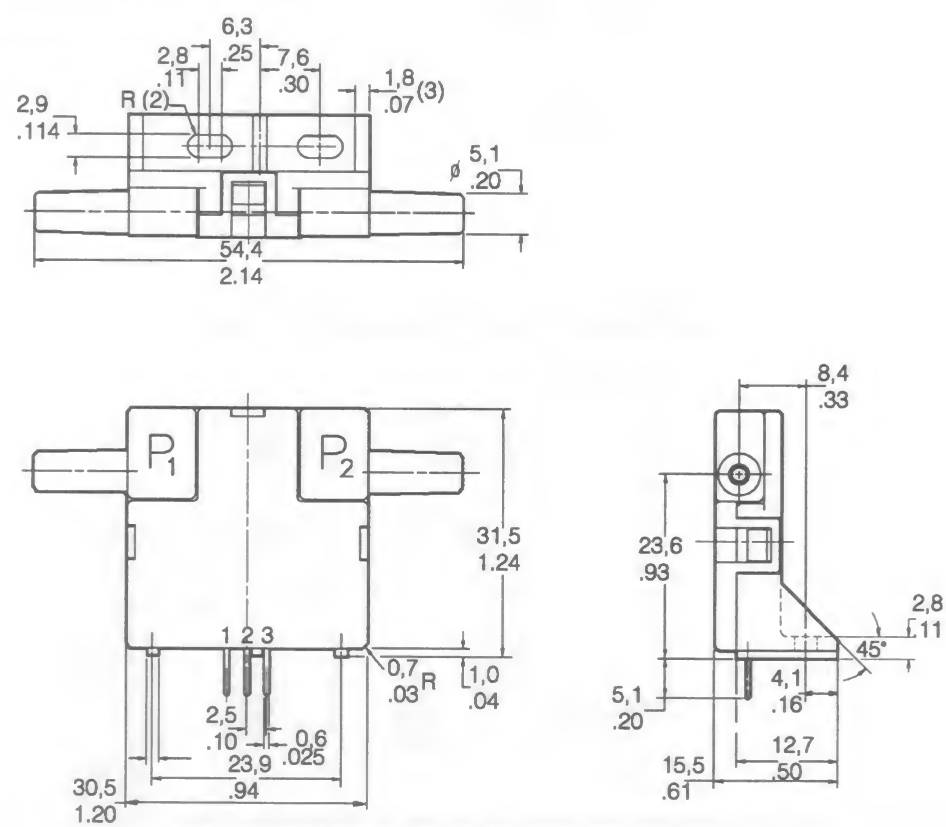
Airflow Sensors
Microbridge Mass Airflow/Amplified

AWM3000 SERIES ORDER GUIDE (Performance Characteristics @ 10.01 ±0.01 VDC, 25°C)

Catalog Listings	AWM3100V	AWM3150V	AWM3200V	AWM3300V
Flow Range (Full Scale)	+200 sccm	+30 sccm		+1000 sccm
Pressure Range (See Application Note 1)			+2.0″ H_2O (5 mBar)	
Output Voltage @ Trim Point	5 VDC @ 200 sccm	3.4 VDC @ 25 sccm	5 VDC @ 2″ H_2O	5 VDC @ 1000 sccm
Null Voltage	1.00 ±0.05 VDC	1.00 ±0.10 VDC	1.00 ±0.08 VDC	1.00 ±0.10 VDC
Null Voltage Shift, Typ. +25° to −25°C, 25° to +85°C	±25 mV	±100 mV	±25 mV	±25 mV
Output Voltage Shift, Max. +25° to −25°C +25° to +85°C	−4% Reading +4% Reading	±5% Reading ±5% Reading	+24% Reading (Note 3) −24% Reading	−5% Reading +5% Reading
Repeatability & Hysteresis, Max.	±0.50% Reading	±1% Reading	±0.50% Reading	±1% Reading
	Min.	**Typ.**	**Max.**	
Excitation VDC (Note 2)	8.0	10±0.01	15	
Power Consumption (mW)	—	50	60	
Response Time (msec) (Note 1)	—	1.0	3.0	
Common Mode Pressure (psi)	—	—	25	
Temperature Range	Operating: −25° to +85°C (−13° to +185°F); Storage: −40° to +90°C (−40° to +194°F)			
Termination	2,54 mm (.100″) centers, 0,635 mm (0.025″) square			
Weight (grams)	10.8			
Shock Rating	100 g peak (5 drops, 6 axes)			

Notes:
1. Initial warm-up time for signal conditioned circuitry is 1 minute max.
2. Output Voltage is ratiometric to supply voltage.
3. Temperature shifts when sensing differential pressure correlates to the density change of the gas over temperature. (See Application Note 1.)
4. Maximum allowable rate of flow change to prevent damage: 5 SLPM/1 sec.

MOUNTING DIMENSIONS (for reference only)



Note: Positive flow direction is defined as proceeding from Port 1 (P1) to Port 2 (P2) and results in positive output. Do not exert a force greater than 4.54kg (10 lbs.) in any direction.

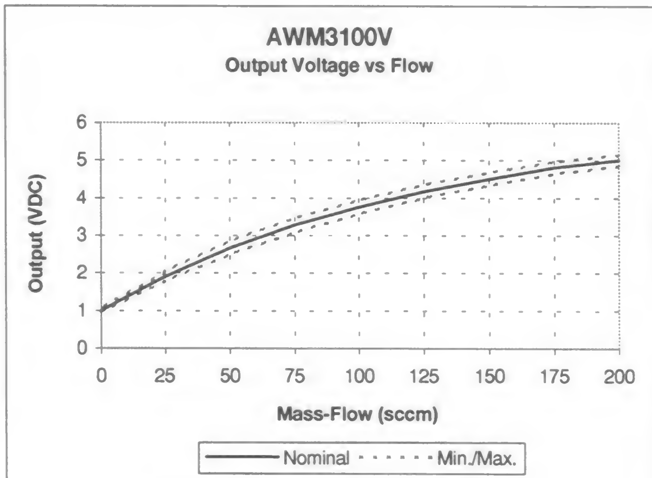
Airflow Sensors
Microbridge Mass Airflow/Amplified

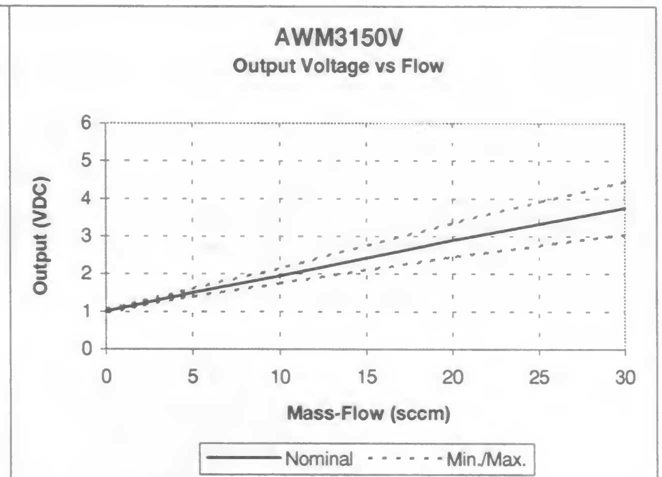
OUTPUT FLOW VS INTERCHANGEABILITY (Note 1) **Performance Characteristics @ 10.0 ±0.01 VDC, 25 C**

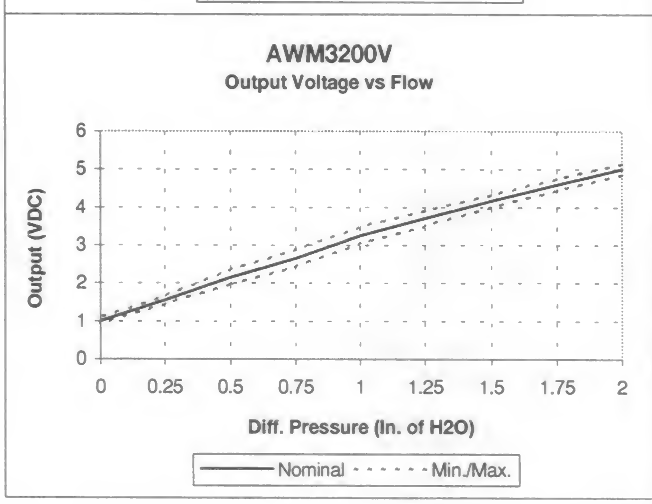
AWM3100V				AWM3150V				AWM3200V (Note 2)				AWM3300V			
Press. mBar	**Flow sccm**	Nom. VDC	Tol. ± VDC	Press mBar	**Flow sccm**	Nom. VDC	Tol. ± VDC	Flow sccm	**Press " H_2O**	Nom. VDC	Tol. ± VDC	Press. mBar	**Flow sccm**	Nom. VDC	Tol. ± VDC
0.49	**200**	5.00	0.15	2.50	**30**	3.75	0.70	60.0	**2.00**	5.00	0.15	3.40	**1000**	5.00	0.15
0.42	**175**	4.80	0.16	1.70	**20**	2.90	0.45	53.0	**1.75**	4.59	0.15	2.90	**900**	4.90	0.16
0.35	**150**	4.50	0.17	0.84	**10**	1.95	0.20	46.0	**1.50**	4.16	0.16	2.40	**800**	4.80	0.17
0.28	**125**	4.17	0.18	0.42	**5**	1.50	0.10	38.0	**1.25**	3.70	0.20	2.00	**700**	4.66	0.18
0.21	**100**	3.75	0.19	0.34	**4**	1.40	0.08	30.0	**1.00**	3.25	0.22	1.60	**600**	4.42	0.19
0.14	**75**	3.27	0.19	0.26	**3**	1.30	0.08	23.0	**0.75**	2.65	0.22	1.20	**500**	4.18	0.20
0.09	**50**	2.67	0.17	0.17	**2**	1.20	0.07	16.0	**0.50**	2.15	0.19	0.80	**400**	3.82	0.21
0.04	**20**	1.90	0.13	0.08	**1**	1.10	0.06	8.0	**0.25**	1.55	0.11	0.54	**300**	3.41	0.19
0.00	**0**	1.00	0.05	0.00	**0**	1.00	0.05	0.0	**0.00**	1.00	0.08	0.31	**200**	2.96	0.17
												0.12	**100**	2.30	0.14
												0.00	**0**	1.00	0.10

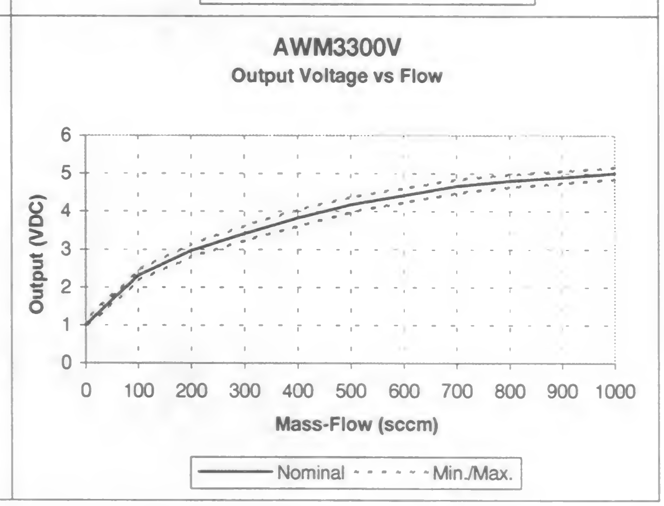
Notes:
1. Numbers in **BOLD** type indicate calibration type, mass flow or differential pressure. Tolerance values apply to calibration type only.
2. Differential pressure calibrated devices are not recommended for flow measurement. Use flow calibrated devices for flow measurement.

OUTPUT CURVES







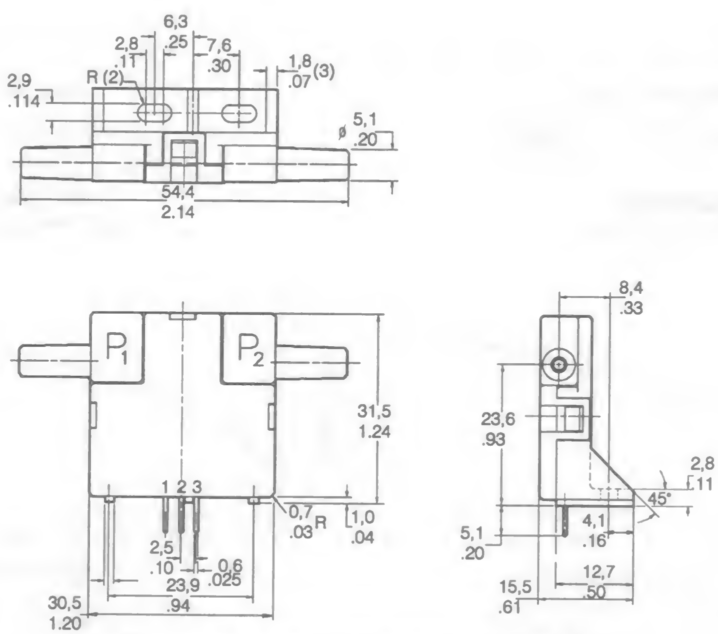


AWM3000 SERIES ORDER GUIDE (Performance Characteristics @ 10.01 ±0.01 VDC, 25°C)

Catalog Listings	AWM3200CR*	AWM3201CR*	AWM3303V
Flow Range (Full Scale)			±1000 sccm (1 SLPM)
Differential Pressure Range	0 - 2″ H_2O (5 mBar)	0 - 0.5″ H_2O (1.25 mBar)	
Output Type	4 - 20 mA DC (linear)	4 - 20 mA DC (linear)	1 - 5 VDC (Note 2)
Output @ Trim Point	20.0 ±1 mA DC @ 2″ H_2O	20.0 ±1 mA DC @ .05″ H_2O	5.00 ±0.150 VDC
Null Output	4.00 ±0.3 mA DC	4.00 ±0.4 mA DC	3.00 ±0.050 VDC
Null Shift +25° to −25°C, +25° to +85°C	±2 mA DC (max.)	±2 mA DC (max.)	±.050 VDC (max.)
Output Shift +25° to −25°C +25° to +85°C	+24% Reading −31% Reading (Note 3)	+32% Reading −32% Reading (Note 3)	−5% Reading +5% Reading
Linearity Error	±5% Reading	±5% Reading	N/A
External Output Load	100 - 300 Ω (Note 4)	100 - 300 Ω (Note 4)	N/A
Response Time (Note 1)	60 msec (max.)	60 msec (max.)	3 msec (max.)
Repeatability & Hysteresis, Max.	±0.50% Reading	±0.50% Reading	±1% Reading
Excitation VDC	10 ±0.01	10±0.01	8-15
Power Consumption (mW)	—	50	100
Common Mode Pressure (psi)	—	—	25
Calibration Gas	Nitrogen		
Temperature Range	Operating: −25° to +85°C (−13° to +185°F); Storage: −40° to +90°C (−40° to +194°F)		
Termination	2,54 mm (.100″) centers, 0,635 mm (0.025″) square		
Weight (grams)	10.8		
Shock Rating	100 g peak (5 drops, 6 axes)		

Notes:
1. Initial warm-up time for signal conditioned circuitry is 1 minute max.
2. Output Voltage is ratiometric to supply voltage.
3. Temperature shifts when sensing differential pressure correlates to the density change of the gas over temperature.
4. Output load connected from V_{OUT} to GND (current sinking).
5. Maximum allowable rate of flow change to prevent damage: 5.0 SLPM/1.0 sec.
* A 5 micron filter must be used on differential pressure sensors.

MOUNTING DIMENSIONS (for reference only)



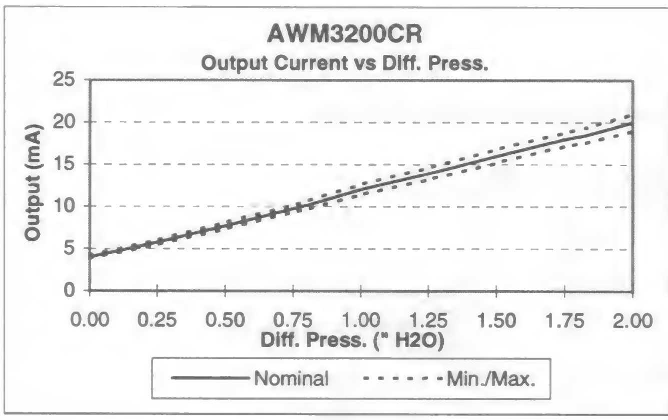
Note: Positive flow direction is defined as proceeding from Port 1 (P1) to Port 2 (P2) and results in positive output. Do not exert a force greater than 4.54kg (10 lbs.) in any direction.

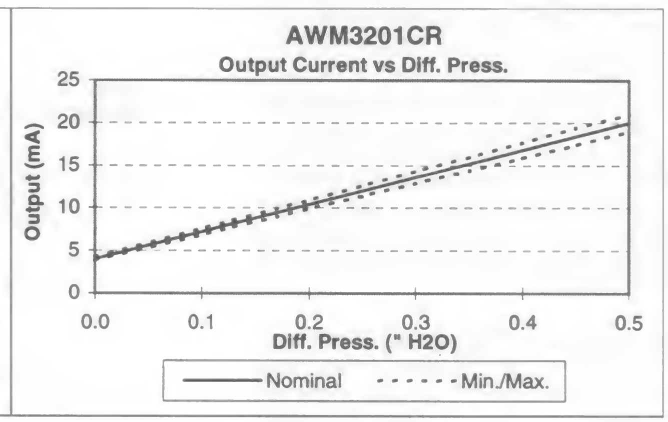
OUTPUT FLOW VS INTERCHANGEABILITY (Note 1) **Performance Characteristics @ 10.0 ± 0.01 VDC, 25 C**

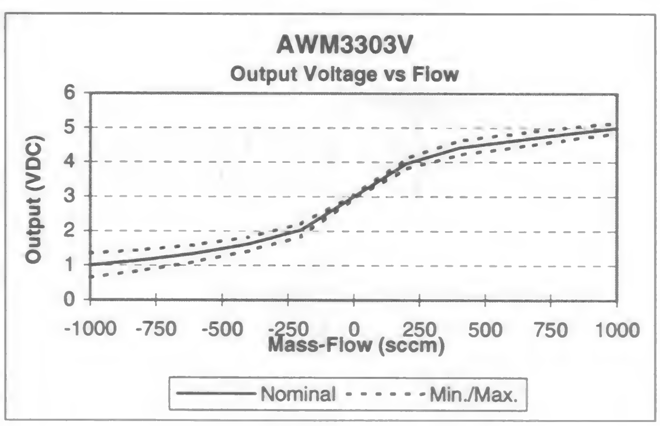
AWM3200CR (Note 2)				AWM3201CR (Note 2)				AWM3303V			
Flow sccm	**Press. " H_2O**	**Nom. mA DC**	**Tol. ± mA DC**	Flow sccm	**Press. " H_2O**	**Nom. mA DC**	**Tol. ± mA DC**	Press mBar	**Flow sccm**	**Nom. VDC**	**Tol. ± VDC**
0	**0.00**	4.00	0.3	0	**0.00**	4.0	0.4	3.49	**1000**	5.00	0.15
7	**0.25**	5.75	0.3	35	**0.10**	7.2	0.4	2.42	**800**	4.82	0.18
15	**0.50**	7.70	0.4	42	**0.13**	8.0	0.4	1.59	**650**	4.67	0.20
22	**0.75**	9.75	0.4	53	**0.17**	9.4	0.5	0.83	**400**	4.42	0.20
25	**0.81**	10.21	0.5	61	**0.20**	10.4	0.5	0.31	**200**	3.96	0.15
30	**1.00**	12.00	0.6	71	**0.25**	12.0	0.6	0.00	**0**	3.00	0.05
37	**1.25**	13.90	0.7	81	**0.30**	13.6	0.7	-0.31	**-200**	2.03	0.18
45	**1.50**	16.00	0.8	87	**0.35**	15.2	0.8	-0.83	**-400**	1.62	0.20
52	**1.75**	18.00	0.8	97	**0.40**	16.8	0.9	-1.59	**-600**	1.35	0.25
55	**1.83**	18.50	0.9	105	**0.45**	18.4	1.0	-2.42	**-800**	1.15	0.30
60	**2.00**	20.00	1.0	113	**0.50**	20.0	1.0	-3.44	**-1000**	1.00	0.35

Notes:
1. Numbers in **BOLD** type indicate calibration type, mass flow or differential pressure. Tolerance values apply to calibration type only.
2. Differential pressure calibrated devices are not recommended for flow measurement. Use flow calibrated devices for flow measurement.

OUTPUT CURVES







Airflow

Airflow Sensors

Microbridge Mass Airflow/Unamplified and Amplified

FEATURES

- Manifold mount/o-ring sealed
- Ceramic flow-tube (non-outgassing), 0-1000 sccm
- Plastic flow tube, 0-6 SLPM
- High common mode pressure (150 psi ceramic flow-tube only)
- Operating temperature up to 125°C (unamplified only)
- High stability at null and full-scale

The AWM40000 Series mass flow sensor family is based on proven microbridge technology and includes both amplified signal conditioned devices and unamplified sensor only devices.

When using the unamplified devices (AWM42150VH and AWM42300V), the heater control circuit in Figure 1 and the sensing bridge supply circuit in Figure 2 are both required for operation per specification. These two circuits are **NOT** on board the sensor and must be supplied in the application. The differential amplifier circuitry in Figure 3 may be useful in providing output gain and/or introducing voltage offsets to the sensor output (Ref. Equation 1).

The amplified devices (AWM43300V and AWM43600V) can be used to increase output gain and introduce voltage offsets. The differential instrumentation amplifier circuitry, heater control circuitry and sensing bridge supply circuitry are all provided onboard the amplified sensors.

Figure 1
Heater Control Circuit

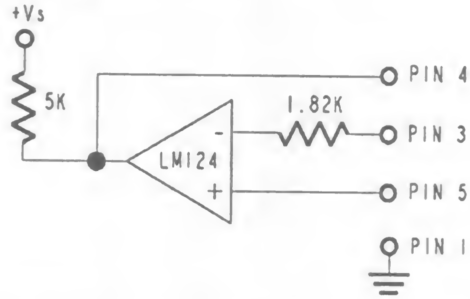


Figure 2
Sensing Bridge Supply Circuit

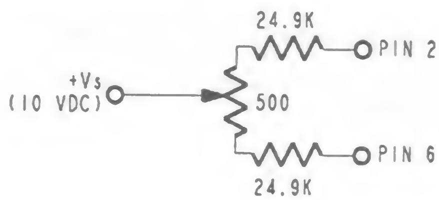
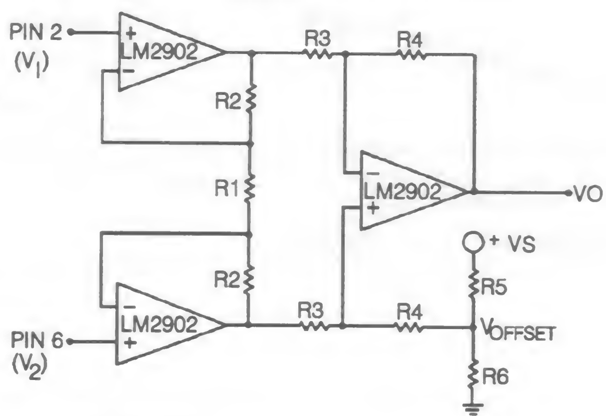


Figure 3
Differential Instrumentation Amplifier Circuit



Equation 1:

$$V_o = \left(\frac{2R_2+R_1}{R_1}\right)\left(\frac{R_4}{R_3}\right)\left(V_2-V_1\right) + V\text{ offset}$$

$$\text{where } V\text{ offset} = V_s\left(\frac{R_6}{R_6+R_5}\right)$$

Airflow Sensors

Microbridge Mass Airflow/Unamplified and Amplified

AWM40000 SERIES ORDER GUIDE (Performance Characteristics @ 10.01 ±0.01 VDC, 25°C)

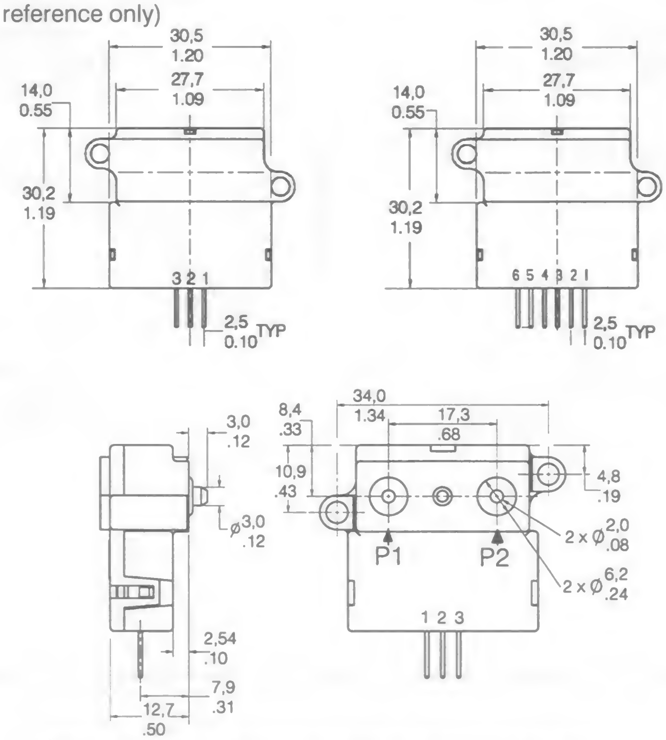
Catalog Listings	AWM42150VH	AWM42300V	AWM43300V	AWM43600V
Flow Range (Full Scale)	±25 sccm	±1000 sccm	+1000 sccm	+6 SLPM
Output Voltage @ Trim Point	8.5 mV ±1.5 mV @ 25 sccm	54.7 mV ±3.7 mV DC @ 1000 sccm	5 V ±0.15 VDC @ 1000 sccm	5 V ±0.15 VDC @ 6 SLPM
Null Voltage	0.0 ±1.0 mVDC	0.0 ±1.5 mVDC	1.0 ±0.05 VDC	1.0 ±0.05 VDC
Null Voltage Shift +25° to −25°C, +25° to +85°C	±0.20 mVDC	±0.20 mVDC	±0.025 VDC	±0.025 VDC
Output Voltage Shift +25° to −25°C +25° to +85°C	+2.5% Reading typ. −2.5% Reading typ.	+2.5% Reading max. −2.5% Reading max.	−5.0% Reading max. +6.0% Reading max.	−6.0% Reading max. +6.0% Reading max.
Power Consumption (mW)	60 (Max.)	60 (Max.)	60 (Max.)	75 (Max.)
Repeatability & Hysteresis	±0.35% Reading (3)	±0.50% Reading	±0.50% Reading	±1.00% Reading
Pressure Drop @ Full Scale (in H_2O)	0.008″ H_2O (Typ.)	1.02 (Typ.)	1.02 (Typ.)	8.00 (Typ.)
	Min.	**Typ.**	**Max.**	
Excitation VDC	8.0	10±0.01	15	
Response Time (msec)	—	1.0	3.0 (Note 1)	
Common Mode Pressure (psi) (max.)	—	—	150 psi (10 Bar)	25 psi (1.7 Bar)
Output Load			NPN (Sinking): 10 mA PNP (Sourcing): 20 mA	
Temperature Range	Operating: −40° to +125°C (−40° to +251°F) Storage: −40° to +125°C (−40° to +251°F)		Operating: −25° to +85°C (−13° to +185°F) Storage: −40° to +90°C (−40° to +194°F)	
Calibration Gas	Nitrogen			
Ratiometricity Error	±0.30% Reading			
Weight (grams)	14 g			11 g
Shock Rating	100 g peak (5 drops, 6 axes)			
Termination	2,54 mm (.100″) centers, 0,635 cm (0.025″) square			

Notes:
1. Response time is typically 1 msec from 10 to 90%.
2. Repeatability & Hysteresis tolerances reflect inherent inaccuracies of the measurement equipment.
3. Maximum allowable rate of flow change to prevent damage: 5.0 SLPM/1.0 sec.

MOUNTING DIMENSIONS (for reference only)

Amplified Sensors

Unamplified Sensors



Note: Positive flow direction is defined as proceeding from Port 1 (P1) to Port 2 (P2), and results in positive output.

Airflow

OUTPUT FLOW VS INTERCHANGEABILITY (Note 1)

Performance Characteristics @ 10.0 ± 0.01 VDC, 25°C

AWM42150VH

Press µBar	Flow sccm	Nom. mV	Tol. ± mV
20	**30**	9.9	1.5
17	**25**	8.5	1.5
14	**20**	6.8	1.5
10	**15**	5.2	1.0
7	**10**	3.5	1.0
3	**5**	1.7	1.0
0	**0**	0.0	1.0

AWM42300V

Press. mBar	Flow sccm	Nom. mV	Tol. ± mV
2.23	**1000**	54.7	2.00
1.52	**800**	53.0	2.0
0.94	**600**	49.3	2.5
0.49	**400**	42.5	3.5
0.19	**200**	29.8	4.0
0.00	**0**	0.0	1.5
-0.19	**-200**	-29.8	4.0
-0.49	**-400**	-42.5	5.0
-0.94	**-600**	-49.3	6.0
-1.52	**-800**	-53.0	6.0
-2.23	**-1000**	-55.2	6.0

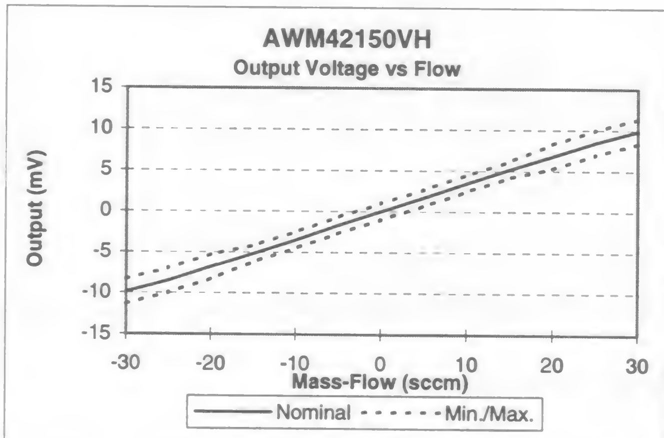
AWM43300V

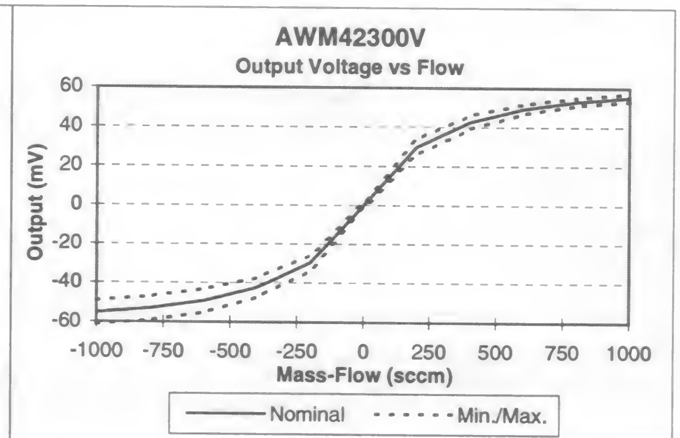
Press. mBar	Flow sccm	Nom. VDC	Tol. ± VDC
2.23	**1000**	5.00	0.15
1.87	**900**	4.97	0.16
1.52	**800**	4.89	0.17
1.16	**700**	4.78	0.18
0.94	**600**	4.63	0.19
0.71	**500**	4.43	0.20
0.50	**400**	4.15	0.21
0.33	**300**	3.76	0.19
0.19	**200**	3.23	0.17
0.08	**100**	2.49	0.14
0.00	**0**	1.00	0.05

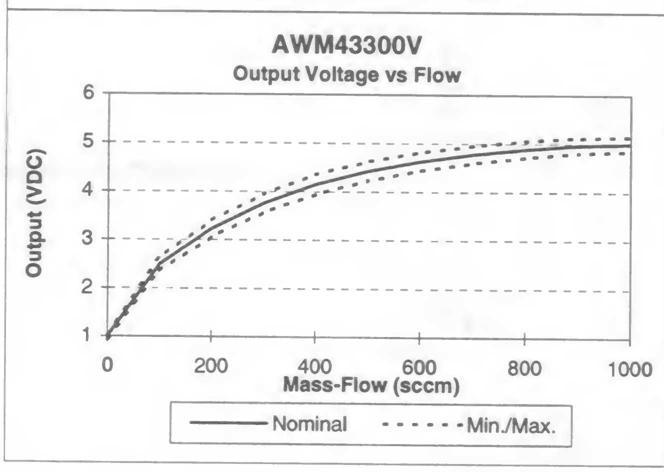
AWM43600V

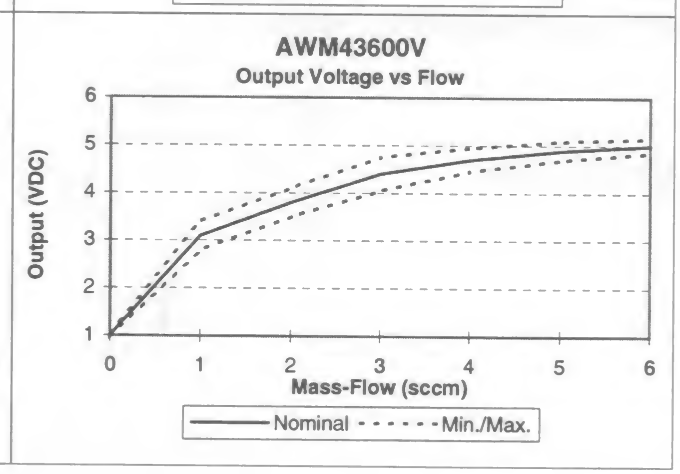
Press. mBar	Flow SLPM	Nom. VDC	Tol. ± VDC
20.0	**6**	5.00	0.15
14.7	**5**	4.89	0.20
9.07	**4**	4.70	0.25
6.40	**3**	4.40	0.35
3.35	**2**	3.80	0.30
1.17	**1**	3.10	0.30
0.00	**0**	1.00	0.05

Notes:
1. Numbers in **BOLD** type indicate calibration type, mass flow or differential pressure.
   Tolerance values apply to calibration type only.









Airflow Sensors
High Flow Mass Airflow/Amplified

FEATURES
- Linear voltage output
- Venturi design
- Remote mounting capability
- Active laser trimming improves interchange ability
- Separate gas calibration types:
  - Ar (argon)
  - N_2 (nitrogen) or
  - CO_2 (carbon dioxide)

In-Line Flow Measurement
AWM5000 Series Microbridge Mass Airflow Sensors feature a venturi type flow housing. They measure flow as high as 20 standard liters per minute (SLPM) while inducing a maximum pressure drop of 2.25″ H_2O. The microbridge chip is in direct contact with the flow stream, greatly reducing error possibilities due to orifice or bypass channel clogging.

Rugged, Versatile Package
The rugged plastic package has been designed to withstand common mode pressures up to 50 psi, and the small sensing element allows 100 gs of shock without compromising performance. The included "AMP" compatible connector provides reliable connection in demanding applications.

On-board Signal Conditioning
Each AWM5000 sensor contains circuitry which performs amplification, linearization, temperature compensation, and gas calibration. Figure 1 (Heater Control Circuit) and Figure 2 (Sensor Bridge Circuit and Amplification Linearization Circuit) illustrate the on-board electrical circuitry for the AWM5000 Series. A 1 to 5 VDC linear output is possible for all listings regardless of flow range (5, 10, 15, or 20 SLPM) or calibration gas (nitrogen, carbon dioxide, nitrous oxide, or argon). All calibration is performed by active laser trimming.

Figure 1

Heater Control Circuit

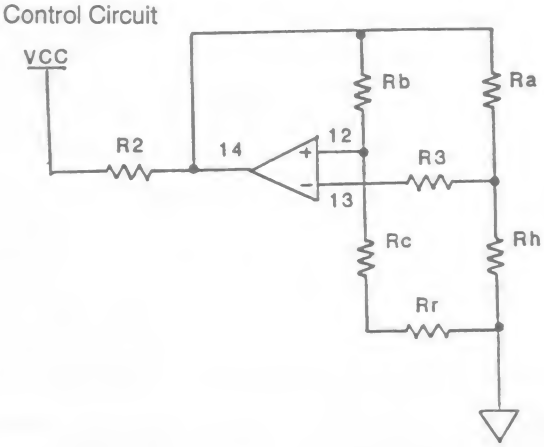
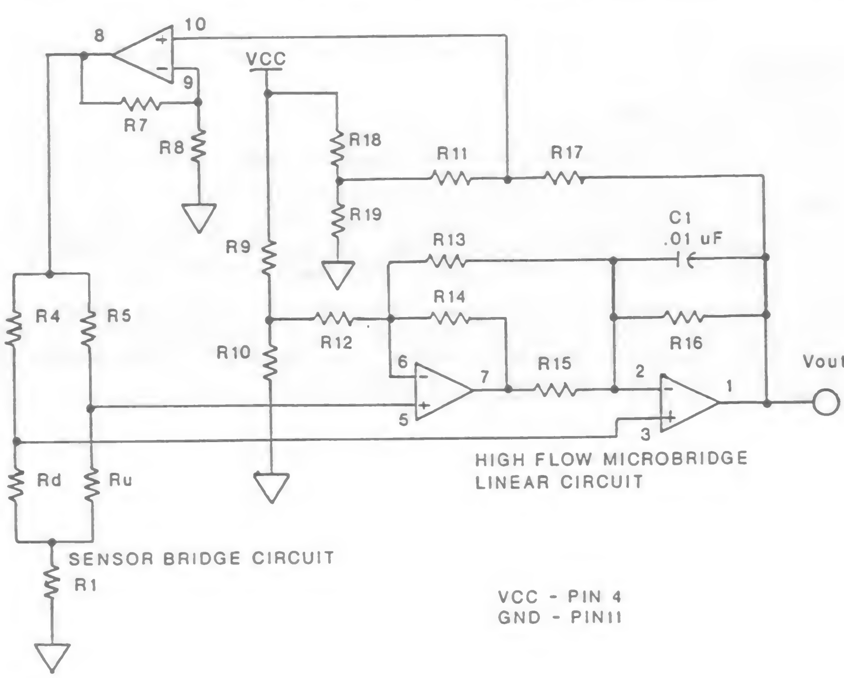


Figure 2

Sensor Bridge Circuit and Amplification Linearization Circuit



Airflow

SPECIFICATIONS (Performance Characteristics @ 10.0 ±0.01 VDC, 25°C)

	AWM5101	AWM5102	AWM5103	AWM5104
Flow Range (Note 3)	0-5 SLPM	0-10 SLPM	0-15 SLPM	0-20 SLPM

Suffix - Calibration gas	**VA** - Argon (Ar)	**VC** - Carbon dioxide (CO_2)	**VN** - Nitrogen (N_2)
	Min.	**Typ.**	**Max.**
Excitation VDC	8	10±0.01	15
Power consumption (mW)	—	—	100
Response time (msec)	—	—	60
Null output VDC	0.95	1	1.05
Null output shift −20° to 70°C	—	±0.050 VDC	±.200 VDC
Common Mode Pressure (psi)	—	—	50
Temperature range	−20° to +70°C, (−4° to 158°F)		
Weight	60 grams (2.12 oz.)		
Shock ratings	100 g peak, 6 msec half-sine (3 drops, each direction of 3 axes)		
Output @ laser trim point	5 VDC @ Full Scale Flow		
Output voltage shift +20° to −25°C, +20° to 70°C	Suffix VA or VN ±7.0% Reading, Suffix VC ±10.0% Reading		
Linearity error (2)	±3.0% Reading (max.)		
Repeatability & Hysteresis	±0.5% Reading (max.)		
Connector (Included) —Four pin receptacle	MICRO SWITCH (SS12143)/AMP (103956-3)		
Leak rate, max	0.1 psi/min. at static condition, (Note 2)		

Notes:
1. Linearity specification applies from 2 to 100% full scale of gas flow range, and does not apply to null output at 0 SLPM.
2. The AWM5000 series product has a leakage spec of less than 0.1 psi per minute at 50 psi common mode pressure. If during installation, the end adapters are twisted with respect to the flowtube, this may compromise the seal between the o-ring and the flowtube and may cause a temporary leak. This leak might be as high as 1 psi or might remain in specification. It will self-reseal as the o-ring takes a new set. Approximately 85% of the leakage will dissipate in 24 hours. Within 48 hours, complete recovery will take place.
3. SLPM denotes standard liters per minute, which is a flow measurement referenced to standard conditions of 0°C/1 bar (sea level), 50% RH.

NOTICE

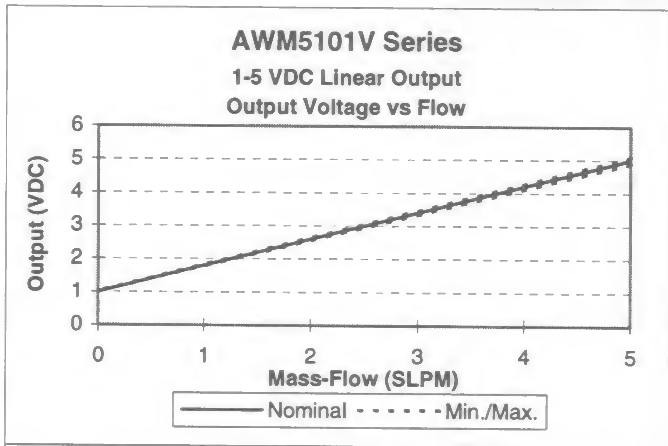
AWM5000—Chimney Effect

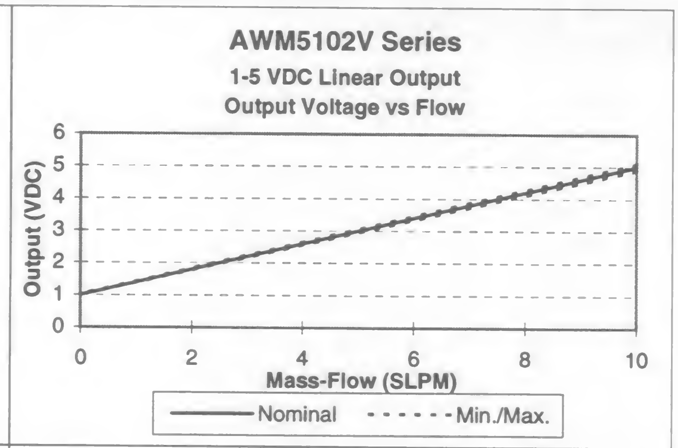
AWM microbridge mass airflow sensors detect mass airflow caused by heat transfer. The thermally isolated microbridge structure consists of a heater resistor positioned between two temperature sensing resistors.

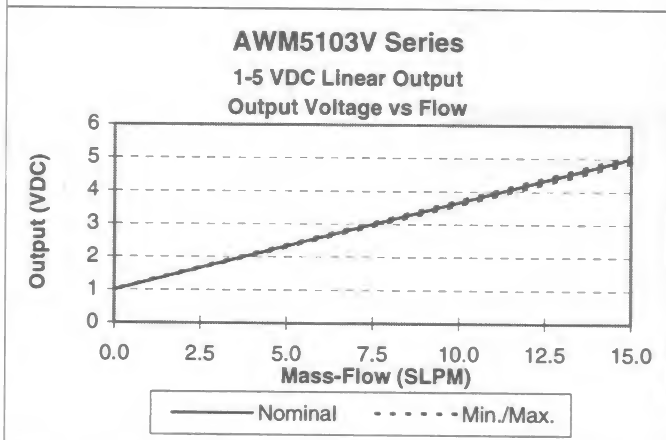
The heater resistor maintains a constant temperature, 160°C above ambient, during sensor operation. Airflow moving past the chip transfers heat from the heater resistor. This airflow warms the downstream resistor and cools the upstream resistor. The temperature change and the resulting change in resistance of the temperature resistors is proportional to the mass airflow across the sensing element.

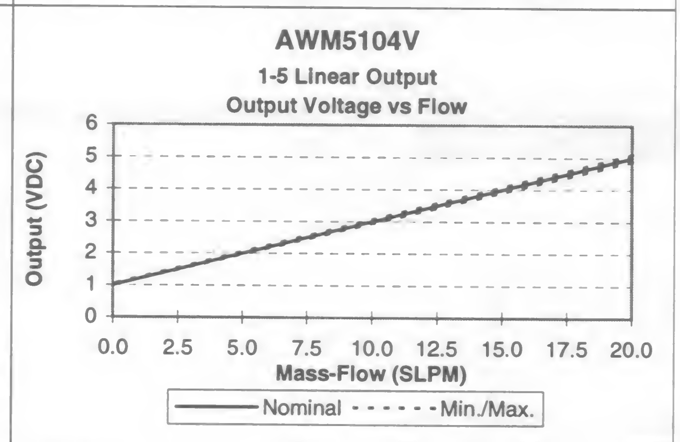
When the sensor is mounted in a vertical position, under zero flow conditions, the sensor may produce an output that is the result of thermally induced convection current. This occurrence is measurable in the AWM5000 Series, particularly in the 5 SLPM versions. When designing the sensor into applications where null stability is critical, avoid mounting the sensor in a vertical position.

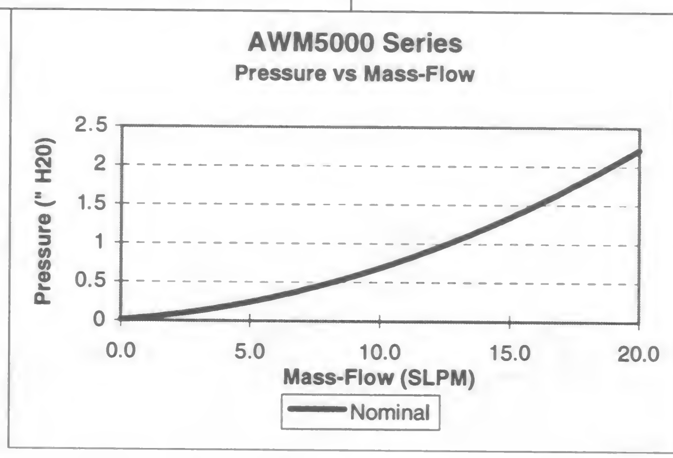
OUTPUT CURVES (Performance Characteristics @ 10.0 ±0.01 VDC, 25°C)











Airflow

AWM5000 ORDER GUIDE

Catalog Listing	Flow Range
AWM5101VA	5 SLPM, Argon calibration
AWM5101VC	5 SLPM, CO_2 calibration (2)
AWM5101VN	5 SLPM, N_2 calibration (1)
AWM5102VA	10 SLPM, Argon calibration
AWM5102VC	10 SLPM, CO_2 calibration (2)
AWM5102VN	10 SLPM, N_2 calibration (1)
AWM5103VA	15 SLPM, Argon calibration
AWM5103VC	15 SLPM, CO_2 calibration (2)
AWM5103VN	15 SLPM, N_2 calibration (1)
AWM5104VA	20 SLPM, Argon calibration
AWM5104VC	20 SLPM, CO_2 calibration (2)
AWM5104VN	20 SLPM, N_2 calibration (1)

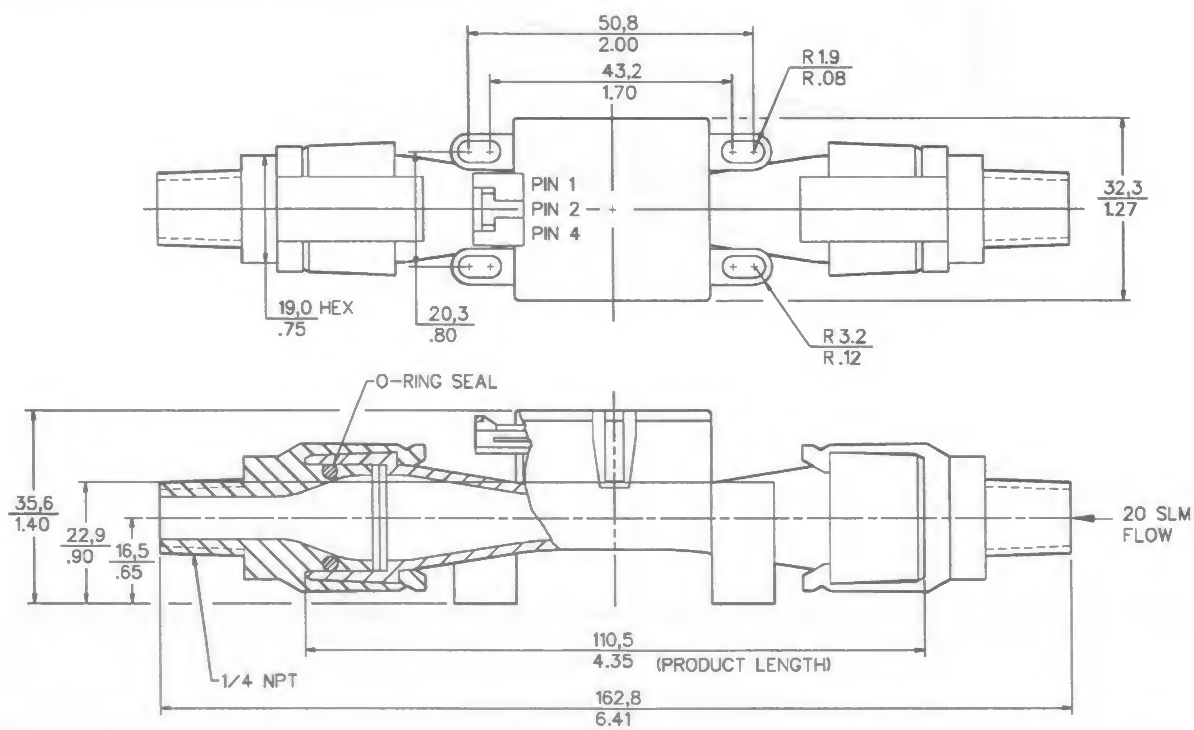
CONNECTOR ORDER GUIDE

Catalog Listing	Description
SS12143	Four pin Electrical connector Connectors use Amp 103956-3

Note: All listings have 1 - 5 VDC linear output with 10 VDC supply over given flow range for a specific calibration gas.
1. N_2 calibration is identical to 0_2 and air calibration.
2. CO_2 calibration is identical to N_2O calibration.
3. For additional gas correction factors, see Application Note 3.

OUTPUT CONNECTIONS
Pin 1 + Supply voltage
Pin 2 Ground
Pin 3 No connection
Pin 4 Output voltage
Arrow on bottom of housing indicates direction of flow.

MOUNTING DIMENSIONS (for reference only)



FEATURES

- Interchangeable without sensor-to-sensor recalibration
- Very small thermal mass for fast response
- Air or liquid temperature sensing
- Linear temperature sensitivity
- Proven thin film processing reliability
- Low cost
- Long term stability
- 2000 ohms nominal resistance at 20°C

TYPICAL APPLICATIONS

- HVAC – room, duct and refrigerant temperature
- Motors – overload protection
- Electronic circuits – semiconductor protection
- Process control – temperature regulation
- Automotive – air or oil temperature
- Appliances – cooking temperature

GENERAL INFORMATION

TD Series temperature sensors from MICRO SWITCH respond rapidly to temperature changes, and are accurate to ±0.7°C at 20°C—completely interchangeable without recalibration. They are RTD (resistance temperature detector) sensors, and provide 8 Ω/°C sensitivity, with inherently near linear outputs.

The sensing element is a silicon chip, 0.040 × 0.050″ with a thin film resistive network pattern. The chips are individually laser trimmed to provide 2000 ohms nominal resistance at room temperature (20°C), accurate to ±0.7°C. Maximum error over the entire operating range of −40 to +150°C (−40 to +302°F) is ±2.5°C. This extremely accurate trimming provides true sensor-to-sensor interchangeability without recalibration of the user circuit.

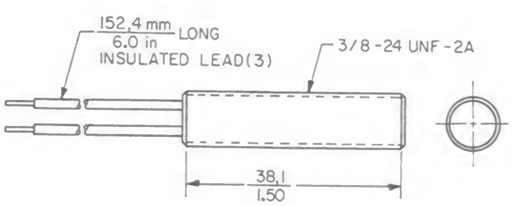
TD4A Liquid temperature sensor

TD4A liquid temperature sensor is a two-terminal threaded anodized aluminum housing. The environmentally sealed liquid temperature sensors are designed for simplicity of installation, such as in the side of a truck. TD4A sensors are not designed for total immersion. Typical response time (for one time constant) is 4 minutes in still air and 15 seconds in still water (unmounted position). The temperature rise is 0.12°C/milliwatt suspended by leads in still air, and 0.08°C/milliwatt when mounted on 1 square foot 0.25″ thick aluminum foil.

TD5A Miniature temperature sensor

The TD5A is a subminiature temperature sensor with three leads (center not connected). It has response times of 11.0 seconds and a temperature rise of .23°C per milliwatt in still air.

TD4A

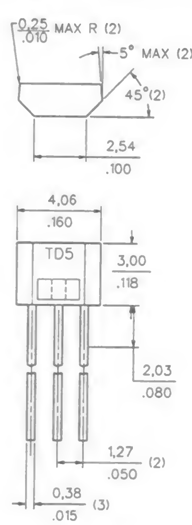


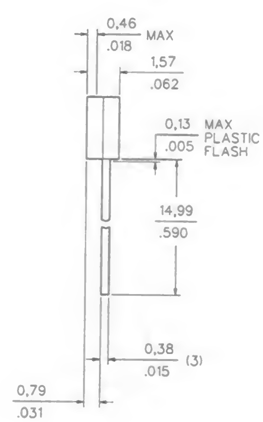
TD ORDER GUIDE

Catalog Listing	Description
TD4A	Liquid temperature sensor, 1.5° threaded (3/8-24 UNF-2A) anodized aluminum housing, two six inch black insulated leads
TD5A	Subminiature package, low cost, fast response time (TO-92)

MOUNTING DIMENSIONS (for reference only)

TD5A





Center lead not connected

Temperature

ABSOLUTE MAXIMUM RATINGS

Operating temperature range	−40 to +150°C (−40 to +302°F)
Storage temperature range	−55 to 165°C (−67 to +338°F)
Voltage	10 VDC Continuous (24 hours)

INTERCHANGEABILITY (with 100 µA maximum current)

Temperature	Resistance (Ohms)	Temperature	Resistance (Ohms)
−40°C (−40°F)	1584 ± 12 (1.9°C)	+60°C (140°F)	2314 ± 9 (1.1°C)
−30°C (−22°F)	1649 ± 11 (1.7°C)	+70°C (158°F)	2397 ± 10 (1.2°C)
−20°C (−4°F)	1715 ± 10 (1.5°C)	+80°C (176°F)	2482 ± 12 (1.4°C)
−10°C (14°F)	1784 ± 9 (1.3°C)	+90°C (194°F)	2569 ± 14 (1.6°C)
0°C (32°F)	1854 ± 8 (1.1°C)	+100°C (212°F)	2658 ± 16 (1.8°C)
+10°C (50°F)	1926 ± 6 (0.8°C)	+110°C (230°F)	2748 ± 18 (2.0°C)
+20°C (68°F)	2000 ± 5 (0.7°C)	+120°C (248°F)	2840 ± 19 (2.0°C)
+30°C (86°F)	2076 ± 5 (0.7°C)	+130°C (266°F)	2934 ± 21 (2.2°C)
+40°C (104°F)	2153 ± 6 (0.8°C)	+140°C (284°F)	3030 ± 23 (2.4°C)
+50°C (122°F)	2233 ± 7 (0.9°C)	+150°C (302°F)	3128 ± 25 (2.5°C)

It is recommended that resistance measurements be made at 100 µA or less to minimize internal heating of the sensor. Measurements at currents up to 1mA will not damage the sensor, but the resistance characteristics should be adjusted for internal heating.

Equation for computing resistance:

$R_T = R_O + (3.84 \times 10^{-3} \times R_O \times T) + (4.94 \times 10^{-6} \times R_O \times T^2)$

R_T = Resistance at temperature T

R_O = Resistance at 0°C

T = Temperature in °C

Figure 2
Linear Output Voltage Circuit

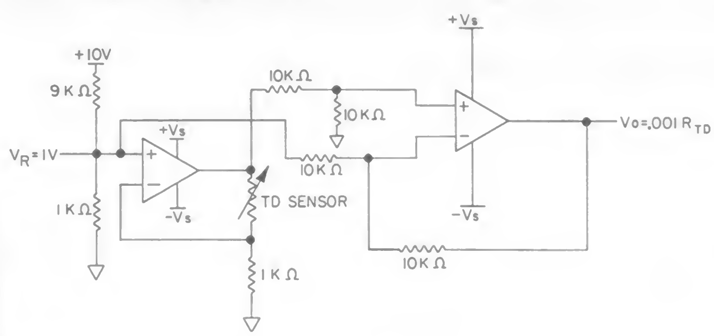
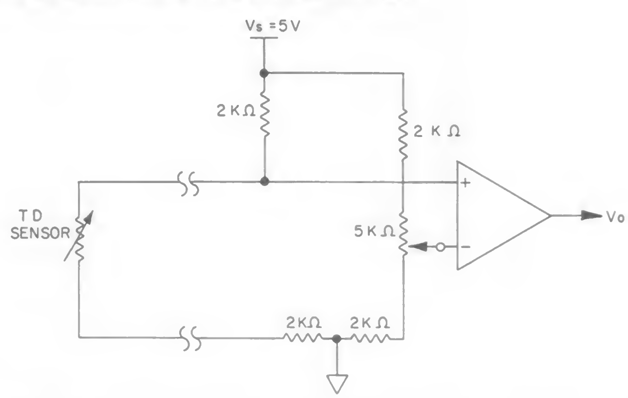


Figure 3
Adjustable Point (Comparator) Interface



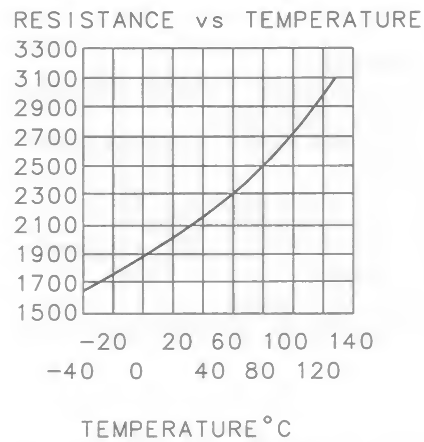
Linearity

±2% (−25 to 85°C)
±3% (−40 to 150°C)
TD sensors can be linearized to within ±0.2%.

Repeatability

±1 Ω

Figure 1
TD Series Resistance vs Temperature



ELECTRICAL INTERFACING

The high nominal resistance, positive temperature coefficient and linear sensitivity characteristics of the TD Series temperature sensors simplifies the task of designing the electrical interface. Figure 2 is a simple circuit that can be used to linearize the voltage output to within 0.2% or a ±0.4°C error over a range of −40° to +150°C (−40° to +302°F).

In some applications, it may be desirable to detect one particular temperature. Figure 3 illustrates one way this can be accomplished. In the comparator circuit shown, the potentiometer can be adjusted to correspond to the desired temperature.

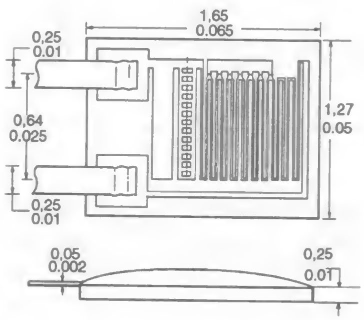
FEATURES
- Linear resistance vs temperature
- Accurate and Interchangeable
- Excellent stability
- Small for fast response
- Wide temperature range
- 3-packaging options

TYPICAL APPLICATIONS
- HVAC - room, duct and refrigerant equipment
- Electronic assemblies - thermal management, temperature compensation
- Process control - temperature regulation

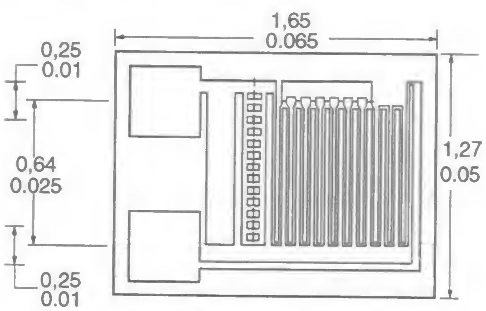
HEL-700 Thin Film Platinum RTDs (Resistance Temperature Detectors) provide excellent linearity, accuracy, stability and interchangeability. Resistance changes linearly with temperature. Laser trimming provides ±0.3°C interchangeability at 25°C.

1000Ω, 375 alpha provides 10X greater sensitivity and signal-to-noise. Both 1000Ω and 100Ω provide interchangeabilities of ±0.6°C or better from -100°C to 100C, and ±3.0°C at 500°C.

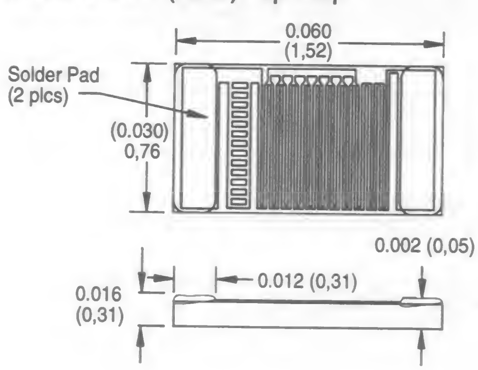
MOUNTING DIMENSIONS (for reference only)
HEL-700 Ribbon Lead



HEL-700 Radial Chip



HEL-700 SMT (Axial) Flip Chip



ORDER GUIDE

HEL-700	Thin Film Platinum RTD			
	-U	1000Ω, 0.00375 Ω/Ω/°C		
	-T	100Ω, 0.00385 Ω/Ω/°C DIN Standard		
		-0	±0.2% Resistance Trim (Standard)	
		-1	±0.1% Resistance Trim (Optional)	
			-A	Radial Ribbon Lead
			-B	Radial Chip
			-C	SMT Axial Flip Chip (1000Ω **ONLY)**

Fig. 1: Linear Output Voltage

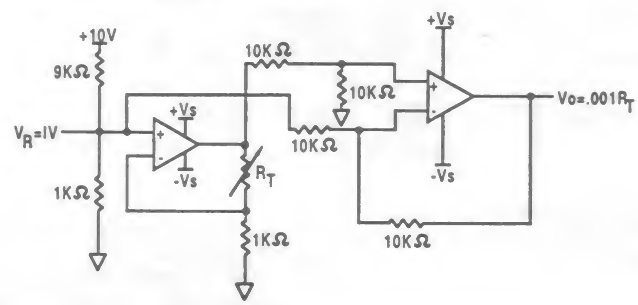
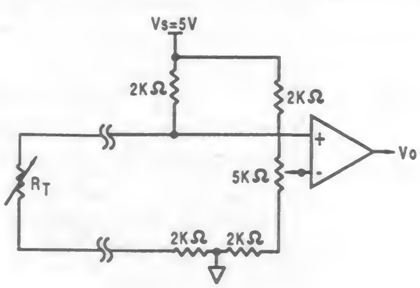


Fig. 2: Adjustable Point (Comparator) Interface



Temperature

FUNCTIONAL BEHAVIOR

$R_T = R_0(1+AT+BT^2-100CT^3+CT^4)$
RT = Resistance (Ω) at temperature T (°C)
R_0 = Resistance (Ω) at 0°C
T = Temperature in °C

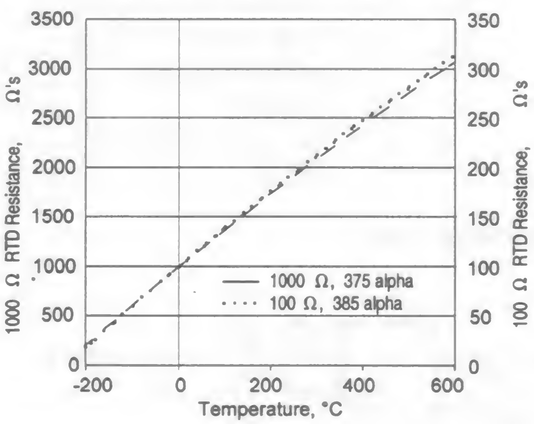
$A = \alpha + \frac{\alpha\delta}{100}$ $B = \frac{-\alpha\delta}{100^2}$ $C_{T<0} = \frac{-\alpha\beta}{100^4}$

CONSTANTS

Alpha, α (°C⁻¹)	0.00375 ±0.000029	0.003850 ±0.000010
Delta, δ (°C)	1.605 ± 0.009	1.4999 ± 0.007
Beta, β (°C)	0.16	0.10863
A ($°C^{-1}$)	3.81×10^{-3}	3.908×10^{-3}
B ($°C^{-2}$)	-6.02×10^{-7}	-5.775×10^{-7}
C ($°C^{-4}$)	-6.0×10^{-12}	-4.183×10^{-12}

Both β = 0 and C = 0 for T>0°C

RESISTANCE VS TEMPERATURE CURVE



ACCURACY VS TEMPERATURE

HEL-700 platinum RTDs are available in two base resistance trim tolerances: ±0.2% or ±0.1%. The corresponding resistance interchangeability and temperature accuracy for these tolerances are:

Tolerance	Standard ±0.2%		Optional ±0.1%	
Temperature (°C)	±ΔR* (Ω)	±ΔT (°C)	±ΔR* (Ω)	±ΔT (°C)
−200	6.8	1.6	5.1	1.2
−100	2.9	0.8	2.4	0.6
0	2.0	0.5	1.0	0.3
100	2.9	0.8	2.2	0.6
200	5.6	1.6	4.3	1.2
300	8.2	2.4	6.2	1.8
400	11.0	3.2	8.3	2.5
500	12.5	4.0	9.6	3.0
600	15.1	4.8	10.4	3.3

*1000Ω RTD. Divide ΔR by 10 for 100Ω RTD.

CAUTION
PRODUCT DAMAGE
The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take normal ESD precautions when handling this product.

SPECIFICATIONS

Sensor Type	Thin film platinum RTD; R_0 = 1000 Ω @ 0°C; alpha = 0.00375 Ω/Ω/°C R_0 = 100 Ω @ 0°C; alpha = 0.00385 Ω/Ω/°C
Temperature Range	−200 to +540°C (−300 to +1000°F)
Temperature Accuracy	±0.5°C or 0.8% of temperature, °C (R_0 ±0.2% trim), whichever is greater ±0.3°C or 0.6% of temperature, °C (R_0 ±0.1% trim), whichever is greater (optional)
Base Resistance and Interchangeability, $R_0 \pm \Delta R_0$	1000 ± 2 Ω (±0.2%) @ 0°C 1000 ± 1 Ω (±0.1%) @ 0°C (optional)
Linearity	±0.1% of full scale for temperatures spanning −40° to +125°C ±2.0% of full scale for temperatures spanning −200° to +540°C
Time Constant	<0.15 seconds in water @ 3 ft./sec. <1 second on metal surfaces: <4 seconds in air @ 10 ft./sec.
Operating Current	2 mA max. For self-heating errors of 1°C 1 mA recommended
Stability	Better than 0.25°C/year: 0.05°C/5 years for occupied environments
Self-Heating	0.3 mW/°C
Insulation Resistance	>50 MΩ @ 50 VDC @ 25°C
Case Material	99% alumina support, vapor deposited alumina passified resistance portion, refractory glass passified overall
Lead Material – Ribbon	Platinum ribbon, 0.002 × 0.010 × 0.16 in. long nominal
Lead Pull Strength – Ribbon	200 grams nominal pulling up from surface

Temperature Sensors
Platinum RTDs

FEATURES
- Linear resistance vs temperature
- Accurate and Interchangeable
- Excellent stability
- Teflon or fiberglass lead wires
- Wide temperature range
- Ceramic case material

TYPICAL APPLICATIONS
- HVAC – room, duct and refrigerant equipment
- Instrument and probe assemblies – temperature compensation
- Process control – temperature regulation

HEL-700 Series elements are fully assembled, ready to use directly or in probe assemblies without the need for fragile splices to extension leads.

The 1000Ω, 375 alpha version, provides 10X greater sensitivity and signal-to-noise. Optional NIST calibrations improve accuracy to ±0.03°C at 0°C.

ORDER GUIDE

HEL-705	28 ga. TFE Teflon, 2-wire only
HEL-707	28 ga. Fiberglass, 2-wire only
HEL-711	28 ga. TFE Teflon (2-wire 1000Ω, 3-wire 100Ω)
HEL-712	28 ga. Fiberglass (2-wire 1000Ω, 3-wire 100Ω)
HEL-716	24 ga. TFE Teflon (2-wire 1000Ω, 3-wire 100Ω)
HEL-717	24 ga. Fiberglass (2-wire 1000Ω, 3-wire 100Ω)
-U	1000Ω, 0.00375 Ω/Ω/°C
-T	100Ω, 0.00385 Ω/Ω/°C DIN Standard
-0	±0.2% Resistance Trim (Standard)
-1	±0.1% Resistance Trim (Optional)
-12	Lead wire length, 12 inches
-00	No NIST calibration
-C1	NIST @ 0°C
-C2	NIST @ 0 & 100°C
-C3	NIST @ 0, 100 & 260°C

MOUNTING DIMENSIONS (for reference only)

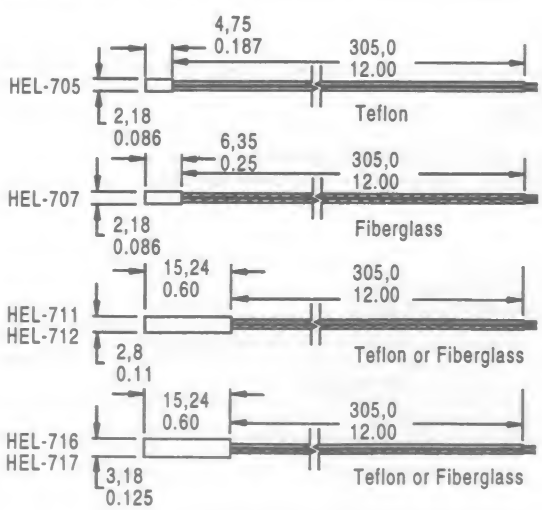


Fig. 1: Wheatstone Bridge 2-Wire Interface

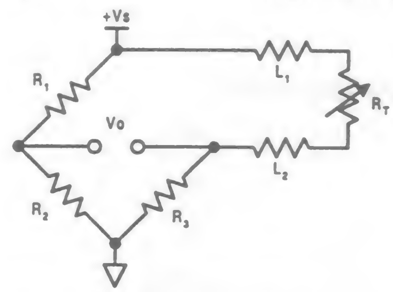


Fig. 2: Linear Output Voltage

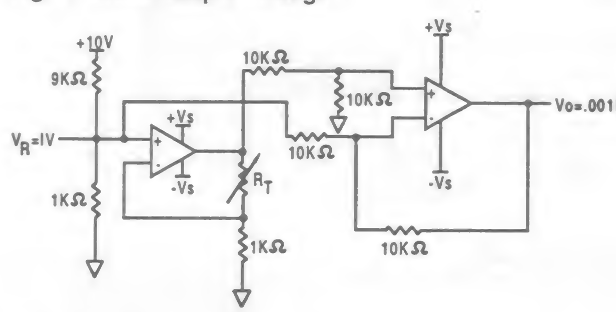
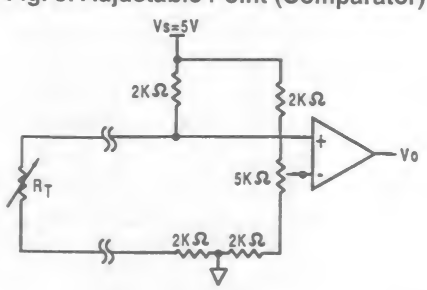


Fig. 3: Adjustable Point (Comparator) Interface



CAUTION
PRODUCT DAMAGE
The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take normal ESD precautions when handling this product.

FUNCTIONAL BEHAVIOR

$R_T = R_0(1+AT+BT^2-100CT^3+CT^4)$
RT = Resistance (Ω) at temperature T (°C)
R_0 = Resistance (Ω) at 0°C
T = Temperature in °C

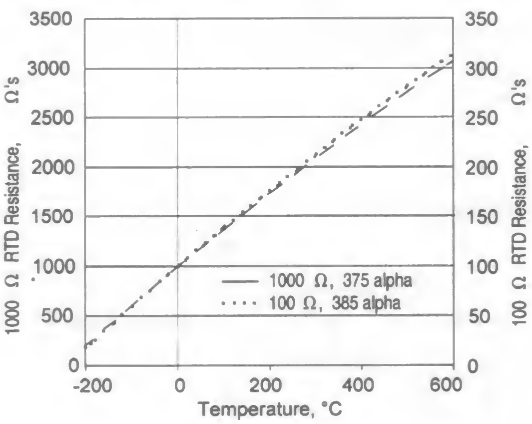
$A = \alpha + \frac{\alpha\,\delta}{100}$ $\qquad B = \frac{-\alpha\,\delta}{100^2}$ $\qquad C_{T<0} = \frac{-\alpha\,\beta}{100^4}$

CONSTANTS

Alpha, α (°C⁻¹)	0.00375 ±0.000029	0.003850 ±0.000010
Delta, δ (°C)	1.605 ± 0.009	1.4999 ± 0.007
Beta, β (°C)	0.16	0.10863
A ($°C^{-1}$)	3.81×10^{-3}	3.908×10^{-3}
B ($°C^{-2}$)	-6.02×10^{-7}	-5.775×10^{-7}
C ($°C^{-4}$)	-6.0×10^{-12}	-4.183×10^{-12}

Both β = 0 and C = 0 for T>0°C

RESISTANCE VS TEMPERATURE CURVE



ACCURACY VS TEMPERATURE

Tolerance	Standard ±0.2%		Optional ±0.1%	
Temperature (°C)	±ΔR* (Ω)	±ΔT (°C)	±ΔR* (Ω)	±ΔT (°C)
−200	6.8	1.6	5.1	1.2
−100	2.9	0.8	2.4	0.6
0	2.0	0.5	1.0	0.3
100	2.9	0.8	2.2	0.6
200	5.6	1.6	4.3	1.2
300	8.2	2.4	6.2	1.8
400	11.0	3.2	8.3	2.5
500	12.5	4.0	9.6	3.0
600	15.1	4.8	10.4	3.3

*1000Ω RTD. Divide Δ by 10 for 100Ω RTD.

NIST CALIBRATION

NIST traceable calibration provides resistance readings at 1, 2 or 3 standard temperature points to yield a resistance versus temperature curve with 10x better accuracy.

Calibration	1 Point	2 Point	3 Point
T (°C)	±ΔT (°C)	±ΔT (°C)	±ΔT (°C)
-200	0.9	—	—
-100	0.5	0.27	0.15
0	0.03	0.03	0.03
100	0.4	0.11	0.07
200	0.8	0.2	0.08
300	1.2	0.33	6.2
400	1.6	0.5	8.3
500	2.0	0.8	9.6
600	2.6	1.2	10.4

SPECIFICATIONS

Sensor Type	Thin film platinum RTD; R_0 = 1000 Ω @ 0°C; alpha = 0.00375 Ω/Ω/°C R_0 = 100 Ω @ 0°C; alpha = 0.00385 Ω/Ω/°C
Temperature Range	TFE Teflon: −200° to +260°C (−320° to +500°F) Fiberglass: −75° to +540°C (−100° to +1000°F)
Temperature Accuracy	±0.5°C or 0.8% of temperature, °C (R_0 ±0.2% trim), whichever is greater ±0.3°C or 0.6% of temperature, °C (R_0 ±0.1% trim), whichever is greater (optional)
Base Resistance and Interchangeability, $R_0 \pm \Delta R_0$	1000 ± 2 Ω (±0.2%) @ 0°C 1000 ± 1 Ω (±0.1%) @ 0°C (optional)
Linearity	±0.1% of full scale for temperatures spanning −40° to +125°C ±2.0% of full scale for temperatures spanning −75° to +540°C
Time Constant	<0.5 sec. 0.85 inch O.D. in water at 3 ft/sec; <1.0 sec, 0.85 inch O.D. in still water
Operating Current	2 mA maximum for self heating errors of <1°C; 1 mA recommended
Stability	<0.25°C/year; 0.05°C per 5 years in occupied environments
Self Heating	<15 mW/°C for 0.85 O.D. typical
Insulation Resistance	>50 MΩ at 50 VDC at 25°C
Construction	Alumina case; Epoxy potting (Teflon leads); Ceramic potting (fiberglass leads)
Lead Material	Nickel coated stranded copper, Teflon or Fiberglass insulated

Temperature Sensors
Platinum RTDs

FEATURES
- Linear resistance vs temperature
- Accurate and Interchangeable
- Excellent stability
- Small size
- Printed circuit mountable
- Ceramic SIP package

TYPICAL APPLICATIONS
- HVAC – room, duct and refrigerant equipment
- Instrument and probe assemblies
- Electronic assemblies – temperature compensation
- Process control – temperature regulation

HEL-775 platinum RTDs are designed to measure temperatures from −55° to +150°C (−67° to 302°F) in printed circuit boards, temperature probes, or other lower temperature applications. Solderable leads in 0.050″ or 0.100″ spacing provide strong connections for wires or printed circuits.

The 1000Ω, 375 alpha version, provides 10x greater sensitivity and signal-to-noise. The 0.050″ lead space models are ideal for probes.

ORDER GUIDE

HEL-775-A	Ceramic SIP pkg. 0.100″ lead spacing		
HEL-775-B	Ceramic SIP pkg. 0.050″ lead spacing		
	-U	1000Ω, 0.00375 Ω/Ω/°C	
	-T	100Ω, 0.00385 Ω/Ω/°C, DIN specification	
		-0	±0.2% Resistance Trim (Standard)
		-1	±0.1% Resistance Trim (Optional)

MOUNTING DIMENSIONS (for reference only) mm/in.

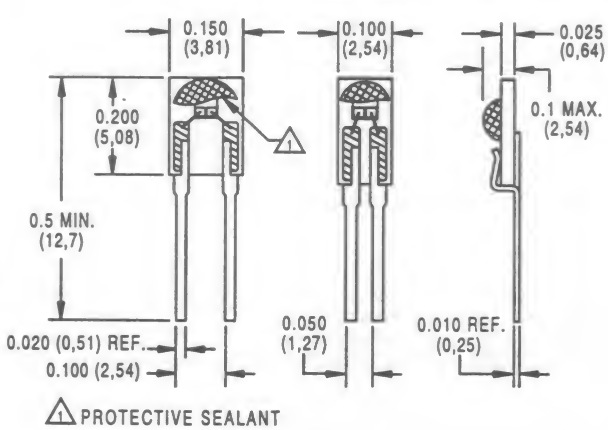


Fig. 1: Wheatstone Bridge 2-Wire Interface

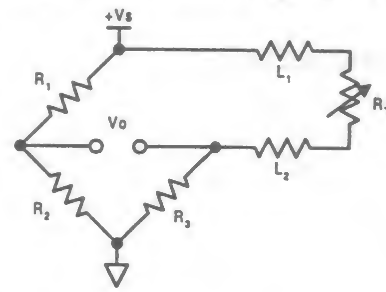


Fig. 2: Linear Output Voltage

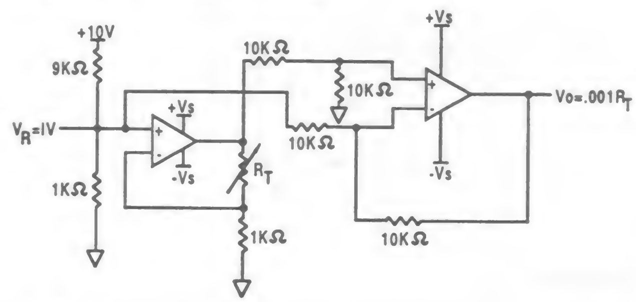
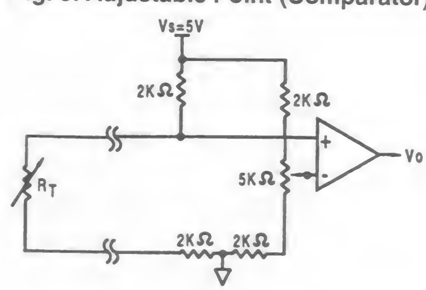


Fig. 3: Adjustable Point (Comparator) Interface



CAUTION
PRODUCT DAMAGE

The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take normal ESD precautions when handling this product.

Temperature Sensors
Platinum RTDs

FUNCTIONAL BEHAVIOR

$R_T = R_0(1+AT+BT^2-100CT^3+CT^4)$
RT = Resistance (Ω) at temperature T (°C)
R_0 = Resistance (Ω) at 0°C
T = Temperature in °C

$A = \alpha + \frac{\alpha\delta}{100}$ $B = \frac{-\alpha\delta}{100^2}$ $C_{T<0} = \frac{-\alpha\beta}{100^4}$

Alpha, α (°C⁻¹)	0.00375 ±0.000029	0.003850 ±0.000010
Delta, δ (°C)	1.605 ± 0.009	1.4999 ± 0.007
Beta, β (°C)	0.16	0.10863
A ($°C^{-1}$)	3.81×10^{-3}	3.908×10^{-3}
B ($°C^{-2}$)	-6.02×10^{-7}	-5.775×10^{-7}
C ($°C^{-4}$)	-6.0×10^{-12}	-4.183×10^{-12}

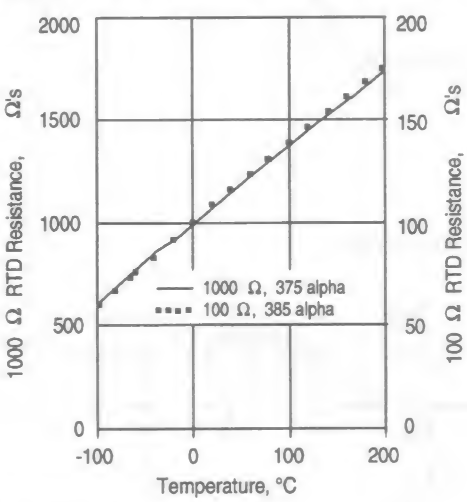
Both β = 0 and C = 0 for T>0°C

ACCURACY VS TEMPERATURE

Tolerance	Standard ±0.2%		Optional ±0.1%	
Temperature (°C)	±ΔR* (Ω)	±ΔT (°C)	±ΔR* (Ω)	±ΔT (°C)
−200	6.8	1.6	5.1	1.2
−100	2.9	0.8	2.4	0.6
0	2.0	0.5	1.0	0.3
100	2.9	0.8	2.2	0.6
200	5.6	1.6	4.3	1.2
300	8.2	2.4	6.2	1.8
400	11.0	3.2	8.3	2.5
500	12.5	4.0	9.6	3.0
600	15.1	4.8	10.4	3.3

* 1000Ω RTD. Divide ΔR by 10 for 100Ω RTD.

RESISTANCE VS TEMPERATURE CURVE



SPECIFICATIONS

Sensor Type	Thin film platinum RTD: R_0 = 1000 Ω @ 0°C; alpha = 0.00375 Ω/Ω/°C R_0 = 100 Ω @ 0°C; alpha = 0.00385 Ω/Ω/°C
Temperature Range	−55° to +150°C (−67° to +302°F)
Temperature Accuracy	±0.5°C or 0.8% of temperature, °C (R_0 ±0.2% trim), whichever is greater ±0.3°C or 0.6% of temperature, °C (R_0 ±0.1% trim), whichever is greater (optional)
Base Resistance and Interchangeability, $R_0 \pm \Delta R_0$	1000 ± 2 Ω (±0.2%) @ 0°C or 100 ± 0.2 Ω (±0.2%) @ 0°C 1000 ± 1 Ω (±0.1%) @ 0°C or 100 + 0.2 Ω (+0.2%) @ 0°C (optional)
Linearity	±0.15% of full scale for temperatures spanning −55° to 150°C
Time Constant	<10 sec. in air at 10 ft./sec.
Operating Current	1 mA maximum in still air for <0.3°C (0.5°F) self heating
Stability	<0.05°C per 5 years in occupied environments
Self Heating HEL-775-A HEL-775-B	 9.7mW/°C nominal in air at 10ft/sec, 4.3mW/°C nominal in enclosed still air 6.8mW/°C nominal in air at 10ft/sec, 3.0mW/°C nominal in enclosed still air
Insulation Resistance	>50 MΩ @ 50 VDC @ 25°C
Construction	Alumina substrate with epoxy protection
Lead Material	Phosphor bronze with bright tin lead 60/40 plating
Lead Configuration	2-wire

Temperature Sensors
Platinum RTDs

FEATURES
- Linear resistance vs temperature
- Accurate and Interchangeable
- Excellent stability
- Small size
- Printed circuit mountable
- Ceramic SIP package

TYPICAL APPLICATIONS
- HVAC – room, duct and refrigerant equipment
- Instrument and probe assemblies
- Electronic assemblies – temperature compensation
- Process control – temperature regulation

HEL-776 and HEL-777 platinum RTDs are designed to measure temperatures from −55° to +150°C (−67° to 302°F) in printed circuit boards, temperature probes, or other lower temperature applications. Solderable leads in 0.050″ or 0.100″ spacing provide strong connections for wires or printed circuits.

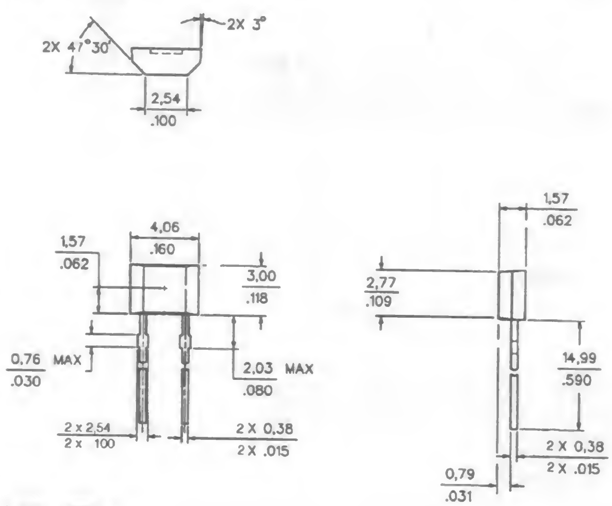
The 1000Ω, 375 alpha version, provides 10x greater sensitivity and signal-to-noise. Both are ideal for air temperature sensing.

ORDER GUIDE

HEL-776-A	Molded SIP pkg. 0.100″ lead spacing		
HEL-777-A	Molded SIP pkg. 0.100″ lead spacing		
	-U	1000Ω, 0.00375 Ω/Ω/°C	
	-T	100Ω, 0.00385 Ω/Ω/°C	
		-0	±0.2% Resistance Trim (Standard)
		-1	±0.1% Resistance Trim (Optional)

MOUNTING DIMENSIONS (for reference only) mm/in.

HEL-776-A



HEL-777-A

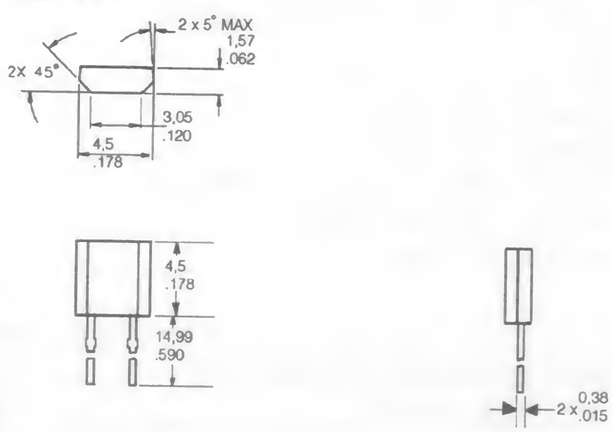


Fig. 1: Wheatstone Bridge 2-Wire Interface

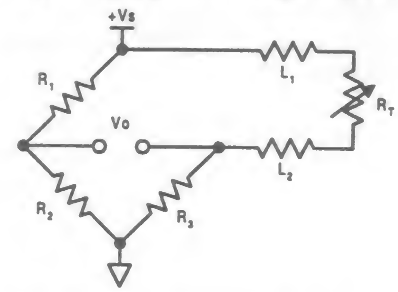


Fig. 2: Linear Output Voltage

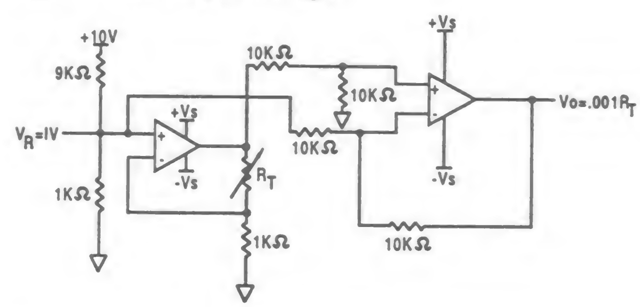
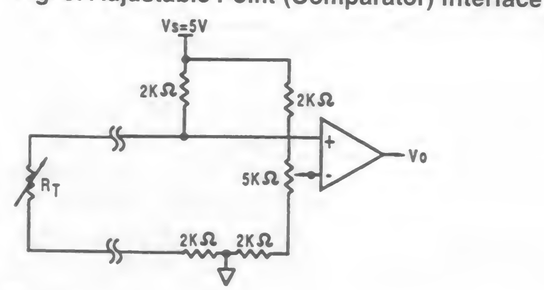


Fig. 3: Adjustable Point (Comparator) Interface



CAUTION
PRODUCT DAMAGE
The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take normal ESD precautions when handling this product.

FUNCTIONAL BEHAVIOR

$R_T = R_0(1+AT+BT^2-100CT^3+CT^4)$
RT = Resistance (Ω) at temperature T (°C)
R_0 = Resistance (Ω) at 0°C
T = Temperature in °C

$A = \alpha + \frac{\alpha\delta}{100}$ $B = \frac{-\alpha\delta}{100^2}$ $C_{T<0} = \frac{-\alpha\beta}{100^4}$

CONSTANTS

Alpha, α (°C^{-1})	0.00375 ±0.000029	0.003850 ±0.000010
Delta, δ (°C)	1.605 ± 0.009	1.4999 ± 0.007
Beta, β (°C)	0.16	0.10863
A (°C^{-1})	3.81×10^{-3}	3.908×10^{-3}
B (°C^{-2})	-6.02×10^{-7}	-5.775×10^{-7}
C (°C^{-4})	-6.0×10^{-12}	-4.183×10^{-12}

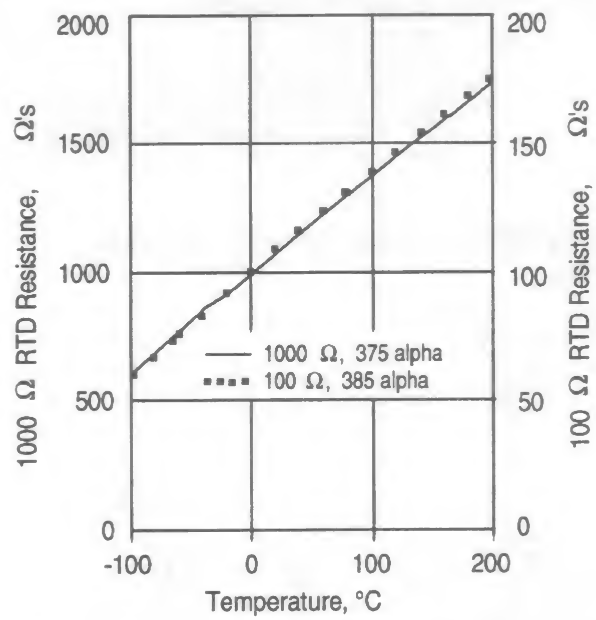
Both β = 0 and C = 0 for T>0°C

ACCURACY VS TEMPERATURE

Tolerance	Standard ±0.2%		Optional ±0.1%	
Temperature (°C)	±ΔR* (Ω)	±ΔT (°C)	±ΔR* (Ω)	±ΔT (°C)
−200	6.8	1.6	5.1	1.2
−100	2.9	0.8	2.4	0.6
0	2.0	0.5	1.0	0.3
100	2.9	0.8	2.2	0.6
200	5.6	1.6	4.3	1.2
300	8.2	2.4	6.2	1.8
400	11.0	3.2	8.3	2.5
500	12.5	4.0	9.6	3.0
600	15.1	4.8	10.4	3.3

* 1000Ω RTD. Divide ΔR by 10 for 100Ω RTD.

RESISTANCE VS TEMPERATURE CURVE



SPECIFICATIONS

Sensor Type	Thin film platinum RTD: R_0 = 1000 Ω @ 0°C; alpha = 0.00375 Ω/Ω/°C R_0 = 100 Ω @ 0°C; alpha = 0.00385 Ω/Ω/°C
Temperature Range	TFE Teflon: −200° to +260°C (−320° to +500°F) Fiberglass: −75° to +540°C (−100° to +1000°F)
Temperature Accuracy	±0.5°C or 0.8% of temperature °C (R_0 ±0.2% trim), whichever is greater ±0.3°C or 0.6% of temperature °C (R_0 ±0.1% trim), whichever is greater (optional)
Base Resistance and Interchangeability, $R_0 \pm \Delta R_0$	1000 ± 2 Ω (±0.2%) @ 0°C or 100 ± 0.2 Ω (±0.2%) @ 0°C 1000 ± 1 Ω (±0.1%) @ 0°C or 100 ± 0.2 Ω (±0.2%) @ 0°C (optional)
Linearity	±0.1% of full scale for temperatures spanning −40° to 125°C ±2.0% of full scale for temperatures spanning −75° to 540°C
Time Constant	<0.5 sec, 0.85 inch O.D. in water at 3 ft/sec; <1.0 sec, 0.85 inch O.D. in still water
Operating Current	2 mA maximum for self heating errors of <1°C; 1 mA recommended
Stability	<0.25°C/year; 0.05°C per 5 years in occupied environments
Self Heating	<15mW/°C for 0.85 O.D. typical
Insulation Resistance	>50 MΩ @ 50 VDC @ 25°C
Construction	Alumina case; Epoxy potting (Teflon leads); Ceramic potting (fiberglass leads)
Lead Material	Nickel coated stranded copper, Teflon or Fiberglass insulated

Temperature Sensors
Platinum RTDs

FEATURES
- Resistance interchangeable
- Accurate
- Linear
- Fast
- Laser trimmed
- Bolt, cement-on or strap-on models

TYPICAL APPLICATIONS
- HVAC – room, duct and refrigerant equipment
- OEM assemblies
- Electronic assemblies – semiconductor protection, temperature compensation
- Process control – temperature regulation

The HRTS is designed to measure surface temperatures from −200° to +480°C (−320° to +900°F) in printed circuit, temperature probe, or other applications.

HRTS surface temperature sensors are fully assembled elements, ready to use, without the need for fragile splices to extension leads.

A thin layer of platinum is deposited on an alumina substrate and laser trimmed to a resistance interchangeability of ±0.2% with ±0.5°C accuracy or ±0.1% with ±0.3°C accuracy. The sensor chip is then glassed, wired and potted or ceramic fired to result in a cylindrical alumina package with either Teflon or fiber glass insulated lead wires.

ORDER GUIDE

HRTS-5760-B	Miniature, ceramic body, 28 ga TFE Teflon insulated leads (2-wire only)			
HRTS-61	Bolt-on, nickel plated copper alloy body, 24 ga fiberglass insulated leads, SST braid, TFE overwrap, spiral armor			
	-T	100Ω, 0.00385 Ω/Ω/°C, 3-wire leads, DIN specification		
	-U	1000Ω, 0.00375 Ω/Ω/°C, 2-wire leads		
		-0	±0.2% Resistance Trim (Standard)	
		-1	±0.1% Resistance Trim (Optional)	
			-12	Standard length, HRTS-5760-B
			-24	Standard length, HRTS-61

Fig. 1: Wheatstone Bridge 2-Wire Interface

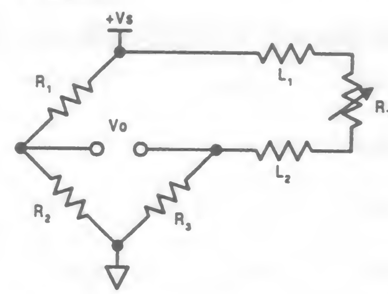
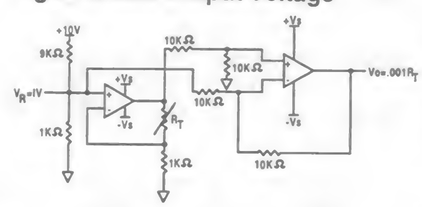
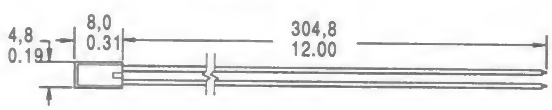


Fig. 2: Linear Output Voltage



MOUNTING DIMENSIONS (for reference only)

HRTS-5760-B



HRTS-61

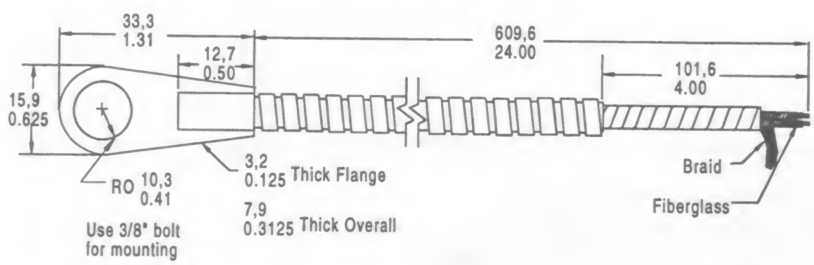
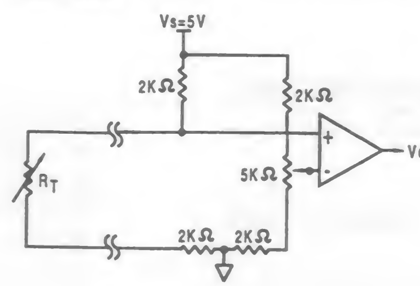


Fig. 3: Adjustable Point (Comparator) Interface



Temperature Sensors
Platinum RTDs

FUNCTIONAL BEHAVIOR

$R_T = R_0(1+AT+BT^2-100CT^3+CT^4)$
RT = Resistance (Ω) at temperature T (°C)
R_0 = Resistance (Ω) at 0°C
T = Temperature in °C

$A = \alpha + \frac{\alpha\delta}{100}$ $B = \frac{-\alpha\delta}{100^2}$ $C_{T<0} = \frac{-\alpha\beta}{100^4}$

CONSTANTS

Alpha, α (°C^{-1})	0.00375 ±0.000029	0.003850 ±0.000010
Delta, δ (°C)	1.605 ± 0.009	1.4999 ± 0.007
Beta, β (°C)	0.16	0.10863
A (°C^{-1})	3.81×10^{-3}	3.908×10^{-3}
B (°C^{-2})	-6.02×10^{-7}	-5.775×10^{-7}
C (°C^{-4})	-6.0×10^{-12}	-4.183×10^{-12}

Both β = 0 and C = 0 for T>0°C

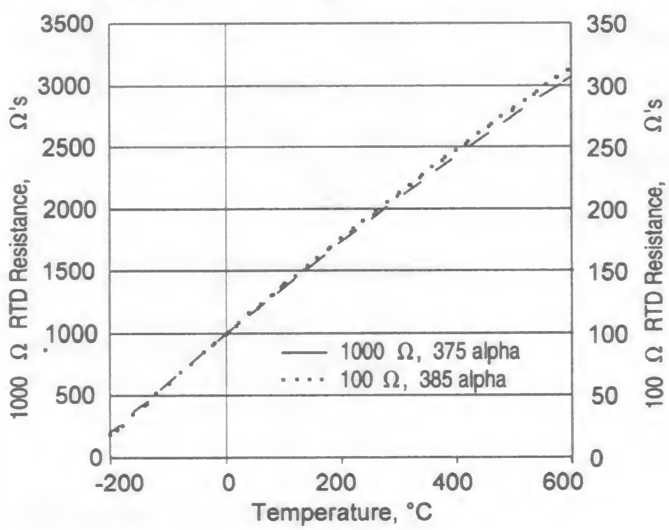
ACCURACY VS TEMPERATURE

HRTS platinum RTDs are available in two base resistance trim tolerances: ±0.2% or ±0.1%. The corresponding resistance interchangeability and temperature accuracy for these tolerances are:

Tolerance	Standard ±0.2%		Optional ±0.1%	
Temperature (°C)	±ΔR* (Ω)	±ΔT (°C)	±ΔR* (Ω)	±ΔT (°C)
−200	6.8	1.6	5.1	1.2
−100	2.9	0.8	2.4	0.6
0	2.0	0.5	1.0	0.3
100	2.9	0.8	2.2	0.6
200	5.6	1.6	4.3	1.2
300	8.2	2.4	6.2	1.8
400	11.0	3.2	8.3	2.5
500	12.5	4.0	9.6	3.0
600	15.1	4.8	10.4	3.3

*1000Ω RTD. Divide ΔR by 10 for 100Ω RTD.

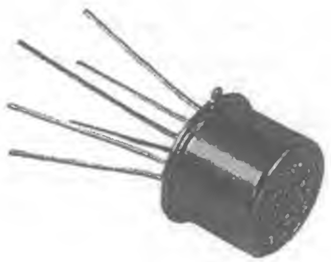
RESISTANCE VS TEMPERATURE CURVE



CAUTION
PRODUCT DAMAGE
The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take normal ESD precautions when handling this product.

SPECIFICATIONS

Sensor Type	Thin film platinum RTD: R_o = 1000 Ω @ 0°C; alpha = 0.00375 Ω/Ω/°C R_o = 100 Ω @ 0°C; alpha = 0.00385 Ω/Ω/°C
Temperature Range	HRTS-5760-B: −200° to +260°C (−320° to +500°F) HRTS-61: −75° to +425°C (−100° to +800°F)
Temperature Accuracy	±0.5°C or 0.8% of temperature @ 0.2% R_o Trim ±0.3°C or 0.6% of temperature @ 0.1% R_o Trim Optional
Time Constant, 1/e	HRTS-5760-B: Typically 0.6 sec. on metal surfaces HRTS-61: Typically 20 sec. On metal surfaces
Operating Current	2 mA max. for self-heating errors of 1°C 1 mA recommended
Self-Heating	0.3 mW/°C
Lead Material	Nickel coated stranded copper, Teflon or Fiberglass insulated



FEATURES
- Linear voltage output vs %RH
- Laser trimmed interchangeability
- High accuracy, fast response
- Chemically resistant
- Stable, low drift performance
- Built-in static protection
- Ideal for dew point and absolute moisture measurements
- TO-39 housing

TYPICAL APPLICATIONS
- Refrigeration
- Drying
- Meteorology
- Battery-powered systems
- OEM assemblies

GENERAL INFORMATION
HIH-3602-A and HIH-3602-C Relative Humidity (RH) sensors combine both relative humidity and temperature sensing in a TO-5 housing with a hydrophobic sintered stainless steel filter

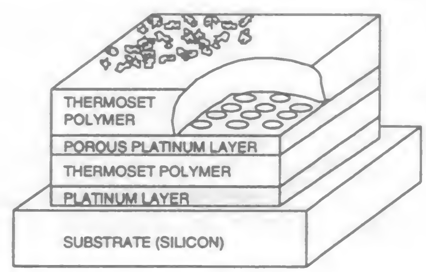
The laser trimmed thermoset polymer capacitive sensing elements have on-chip integrated signal conditioning. The temperature sensor is thermally connected with the RH sensor making the HIH-3602-A/C ideal for measuring dew point and other absolute moisture terms. Factory calibration data supplied with each sensor allows individually matched downstream electronics and ±2% RH total accuracy.

ORDER GUIDE

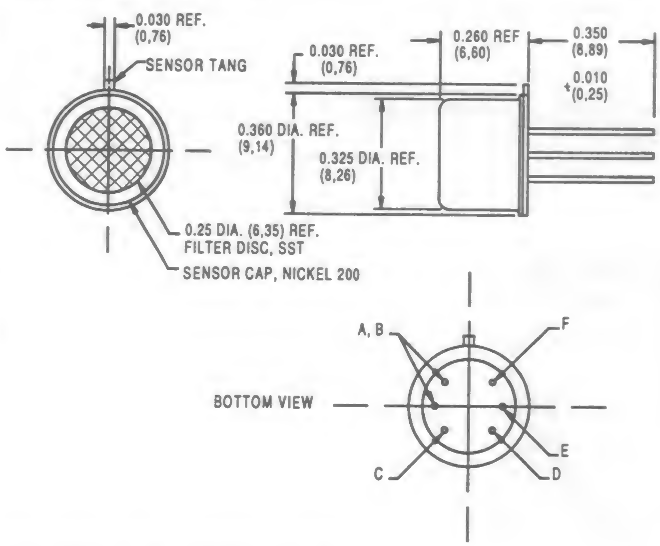
Catalog Listing	Description
HIH-3602-A	Monolithic IC humidity sensor with integral thermistor in TO-5 can
HIH-3602-C	Monolithic IC humidity sensor with integral precision RTD in TO-5 can

NIST CALIBRATION
Each HIH-3602-A or HIH-3602-C sensor includes a sensor specific NIST calibration and data printout. Sensors are not individually serialized.

RH SENSOR CONSTRUCTION
Sensor construction consists of a planar capacitor with a second polymer layer to protect against dirt, dust, oils and other hazards.



MOUNTING DIMENSIONS (for reference only)
HIH-3602-A and HIH-3602-C



CAUTION
PRODUCT DAMAGE

The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take normal ESD precautions when handling this product.

INTERNAL PIN CONNECTIONS

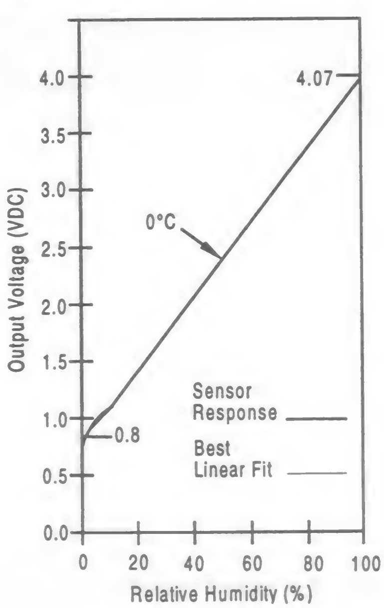
0.018 (0,46) dia. lead gold plated (6 places)	
A, B	(HIH-3602-A) Thermistor for temperature compensation
A, B	(HIH-3602-C) RTD for temperature compensation
C	+VDC supply
D	(−) Power or ground
E	VDC out
F	Case ground

PERFORMANCE SPECIFICATIONS

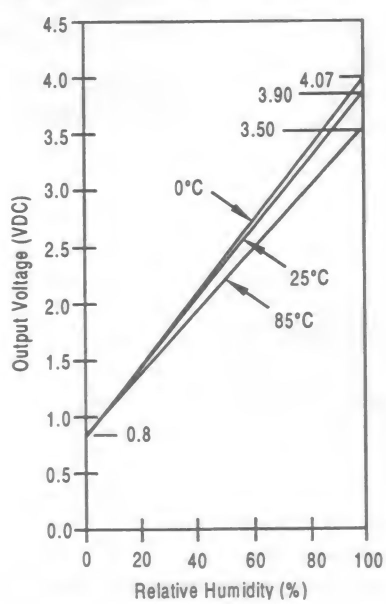
Catalog Listing	HIH-3602-A	HIH-3602-C
Temperature Sensor	Rb = 100 kΩ ±5% @ 25°C, NTC 0-50°C, β = 4143K, T = °K R(T) = Rb exp (β/T-β/298.15)	1000Ω ±0.2% @ 0°C Thin Film Platinum RTD alpha = 0.00375 Ω/Ω/°C
Temperature Accuracy	±3.0°C @ 25°C	±0.5°C @ 25°C
RH Accuracy[1]	±2% RH, 0-100% RH non-condensing, 25°C, V_{supply} = 5 VDC	
RH Interchangeability	±5% RH, 0-60% RH; ±8% @ 90% RH	
RH Linearity	±0.5% RH typical	
RH Hysteresis	±1.2% of RH span maximum	
RH Repeatability	±0.5% RH	
RH Response Time, 1/e	50 sec in slowly moving air at 25°C	
RH Stability	±1% RH typical at 50% RH in 5 years	
Power Requirements Voltage Supply Current Supply	 4 to 5.8 VDC, sensor calibrated at 5 VDC 200 μA at 5 VDC, 2 mA typical at 9 VDC	
Voltage Output V_{supply} = 5 VDC Drive Limits	$V_{out} = V_{supply}$ (0.0062 (Sensor RH) +0.16), typical @ 25°C (Data printout provides a similar, but sensor specific, equation at 25°C.) 0.8 to 3.9 VDC output @ 25°C typical Push/pull symmetric; 50 μA typical, 20 μA minimum, 100 μA maximum Turn-on ≤0.1 second	
Temp. Compensation Effect @ 0% RH Effect @ 100% RH	True RH = (Sensor RH)/(1.093-.0012T), T in °F True RH = (Sensor RH)/(1.0546-0.00216T), T in °C ±0.007% RH/°C (negligible) −0.22% RH/°C (<1% RH effect typical in occupied space systems above 15°C (59°F))	
Humidity Range Operating Storage	 0 to 100% RH, non-condensing[1] 0 to 90% RH, non-condensing	
Temperature Range Operating Storage	 −40° to 85°C (−40° to 185°F) −40° to 125°C (−40° to 275°F)	
Package	TO-5 with 60μ hydrophobic sintered stainless steel filter, resists condensation	
Handling	Static sensitive diode protected to 15 kV maximum	

1. Extended exposure to ≥90% RH causes a reversible shift of 3% RH.

OUTPUT VOLTAGE VS RELATIVE HUMIDITY (at 0°C)



OUTPUT VOLTAGE VS RELATIVE HUMIDITY (at 0°C, 25°C, and 85°C)



Humidity Sensors
Relative Humidity

FEATURES
- Linear voltage output vs %RH
- Laser trimmed interchangeability
- High accuracy
- Fast response
- Stable, low drift performance
- Chemically resistant
- Built-in static protection

TYPICAL APPLICATIONS
- Refrigeration
- Drying
- Meteorology
- Battery-powered systems
- OEM assemblies

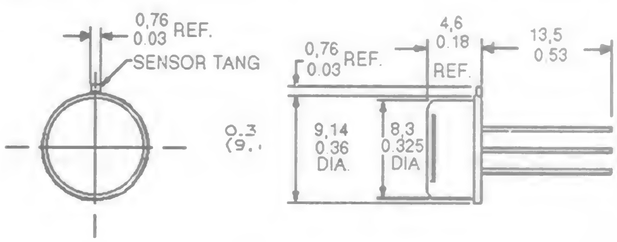
GENERAL INFORMATION
The HIH-3602-L IC (Integrated Circuit) Relative Humidity (RH) sensor delivers instrumentation quality RH sensing performance in a rugged, low cost, slotted TO-39 housing.

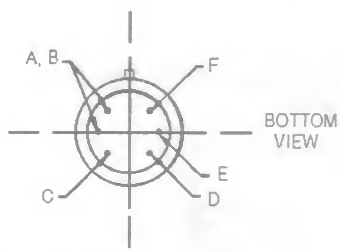
The RH sensor is a thermoset polymer capacitive sensing element with on-chip integrated signal conditioning. On-board signal conditioning reduces product development times while a typical current draw of only 200 µA makes the HIH-3602-L perfect for battery powered systems.

ORDER GUIDE

Catalog Listing	Description
HIH-3602-L	Integrated circuit humidity sensor in TO-39 can
HIH-3602-L-CP	Integrated circuit humidity sensor in TO-39 can with calibration and data printout

MOUNTING DIMENSIONS (for reference only)



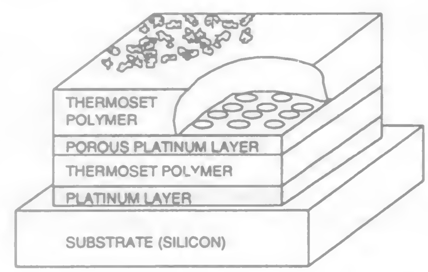


INTERNAL PIN CONNECTIONS

0.018 (0,46) dia. lead gold plated (6 places)	
A, B	No connection
C	+VDC supply
D	(−) Power or ground
E	VDC out
F	Case ground

NIST CALIBRATION
HIH-3602-L may be ordered with a NIST calibration and sensor specific data printout. Append "−CP" to the model number to order.

RH SENSOR CONSTRUCTION
Sensor construction consists of a planar capacitor with a second polymer layer to protect against dirt, dust, oils and other hazards.



CAUTION
PRODUCT DAMAGE

The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take normal ESD precautions when handling this product.

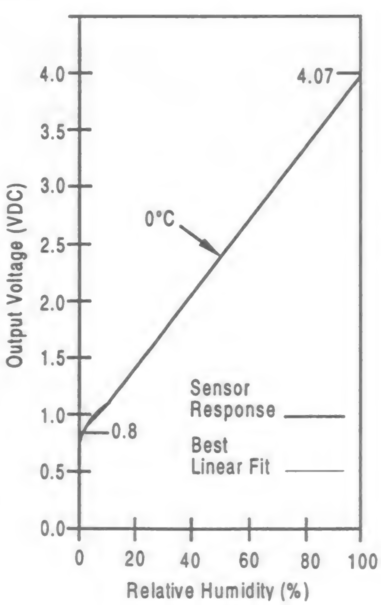
Humidity

PERFORMANCE SPECIFICATIONS

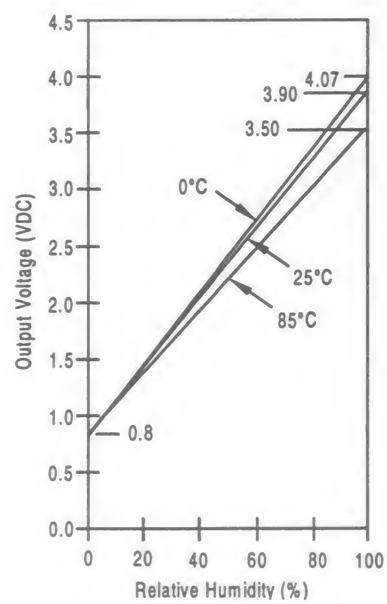
Parameter	Conditions
RH Accuracy[1]	±2% RH, 0-100% RH non-condensing, 25°C, V_{supply} = 5 VDC
RH Interchangeability	±5% RH, 0-60% RH; ±8% @ 90% RH typical
RH Linearity	±0.5% RH typical
RH Hysteresis	±1.2% of RH span maximum
RH Repeatability	±0.5% RH
RH Response Time, 1/e	30 seconds in slowly moving air at 25°C
RH Stability	±1% RH typical at 50% RH in 5 years
Power Requirements	
Voltage Supply	4 to 5.8 VDC, sensor calibrated at 5 VDC
Current Supply	200 µA at 5 VDC, 2 mA typical at 9 VDC
Voltage Output	$V_{out} = V_{supply}$ (0.0062 (Sensor RH) +0.16), typical @ 25°C (Data printout provides a similar, but sensor specific, equation at 25°C.)
V_{supply} = 5 VDC	0.8 to 3.9 VDC output @ 25°C typical
Drive Limits	Push/pull symmetric; 50 µA typical, 20 µA minimum, 100 µA maximum Turn-on ≤0.1 second
Temp. Compensation	True RH = (Sensor RH)/(1.093-.0012T), T in °F True RH = (Sensor RH)/(1.0546-0.00216T), T in °C
Effect @ 0% RH	±0.007% RH/°C (negligible)
Effect @ 100% RH	−0.22% RH/°C (<1% RH effect typical in occupied space systems above 15°C (59°F))
Humidity Range	
Operating	0 to 100% RH, non-condensing
Storage	0 to 90% RH, non-condensing[1]
Temperature Range	
Operating	−40°C to 85°C (−40°F to 185°F)
Storage	−40°C to 125°C (−40°F to 257°F)
Package	Six pin TO-39 with slotted nickel cap[2]
Handling	Static sensitive, diode protected to 15 kV maximum

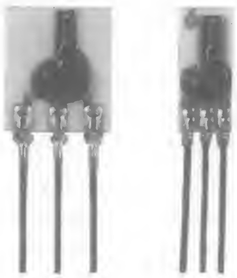
Notes:
1. Extended exposure to ≥90% RH causes a reversible shift of 3% RH.
2. This sensor is light sensitive. For best results, shield the sensor from bright light.

OUTPUT VOLTAGE VS RELATIVE HUMIDITY (at 0°C)



OUTPUT VOLTAGE VS RELATIVE HUMIDITY (at 0°C, 25°C, and 85°C)





FEATURES
- Linear voltage output vs %RH
- Laser trimmed interchangeability
- Low power design
- High accuracy
- Fast response time
- Stable, low drift performance
- Chemically resistant

TYPICAL APPLICATIONS
- Refrigeration
- Drying
- Meteorology
- Battery-powered systems
- OEM assemblies

GENERAL INFORMATION
The HIH-3605 monolithic IC (Integrated Circuit) humidity sensor is designed specifically for high volume OEM (Original Equipment Manufacturer) users. Direct input to a controller or other device is made possible by this sensor's linear voltage output. With a typical current draw of only 200 µA, the HIH-3605 is ideally suited for low drain, battery powered systems.

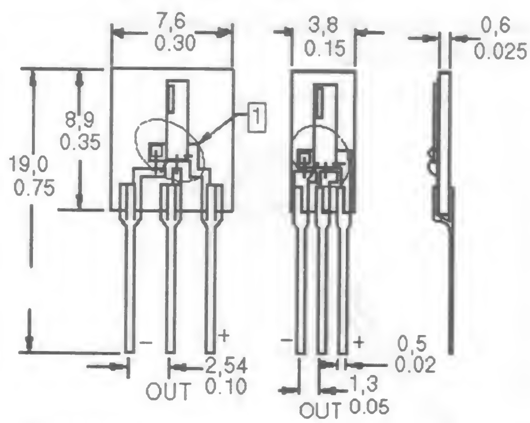
The HIH-3605 delivers instrumentation quality RH sensing performance in a low cost, solderable SIP (Single In-line Package). Available in two lead spacing configurations, the RH sensor is a laser trimmed thermoset polymer capacitive sensing element with on-chip integrated signal conditioning.

ORDER GUIDE

Catalog Listing	Description
HIH-3605-A	Integrated circuit humidity sensor, 0.100 in. lead pitch SIP
HIH-3605-A-CP	Integrated circuit humidity sensor, 0.100 in. lead pitch SIP with calibration and data printout
HIH-3605-B	Integrated circuit humidity sensor, 0.050 in. lead pitch SIP
HIH-3605-B-CP	Integrated circuit humidity sensor, 0.050 in. lead pitch SIP with calibration and data printout.

MOUNTING DIMENSIONS (for reference only)

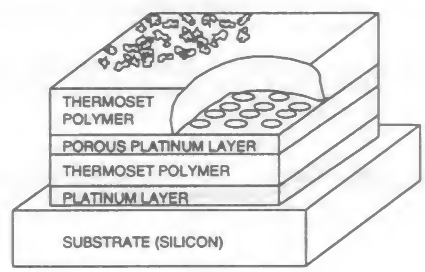
HIH-3605-A HIH-3605-B



1 Protective Sealant

NIST CALIBRATION
HIH-3605 sensors may be ordered with a NIST calibration and sensor specific data printout. Append "–CP" to the model number to order.

RH SENSOR CONSTRUCTION
Sensor construction consists of a planar capacitor with a second polymer layer to protect against dirt, dust, oils and other hazards.



CAUTION
PRODUCT DAMAGE
The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take normal ESD precautions when handling this product.

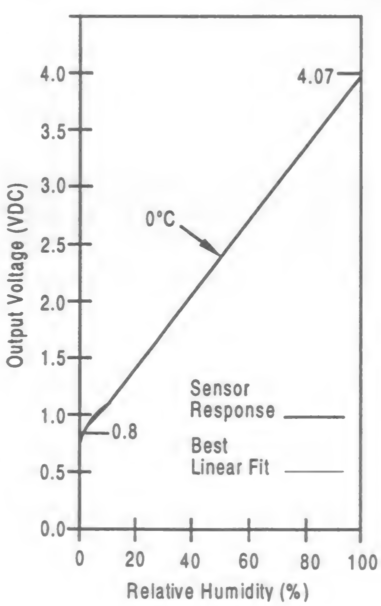
Humidity Sensors
Relative Humidity

PERFORMANCE SPECIFICATIONS

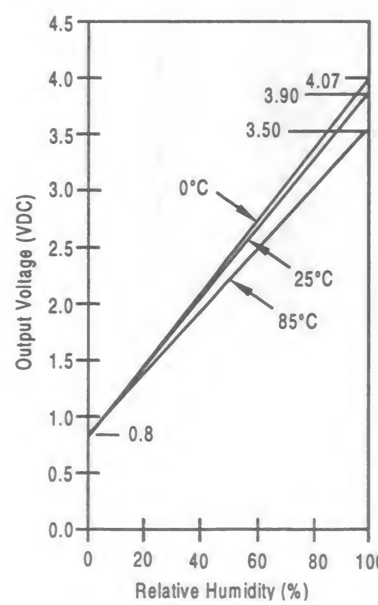
Parameter	Conditions
RH Accuracy[1]	±2% RH, 0-100% RH non-condensing, 25°C, V_{supply} = 5 VDC
RH Interchangeability	±5% RH, 0-60% RH; ±8% @ 90% RH typical
RH Linearity	±0.5% RH typical
RH Hysteresis	±1.2% of RH span maximum
RH Repeatability	±0.5% RH
RH Response Time, 1/e	15 sec in slowly moving air at 25°C
RH Stability	±1% RH typical at 50% RH in 5 years
Power Requirements Voltage Supply Current Supply	 4 to 5.8 VDC, sensor calibrated at 5 VDC 200 µA at 5 VDC, 2 mA typical at 9 VDC
Voltage Output V_{supply} = 5 VDC Drive Limits	V_{out} = V_{supply} (0.0062 (Sensor RH) +0.16), typical @ 25°C (Data printout provides a similar, but sensor specific, equation at 25°C.) 0.8 to 3.9 VDC output @ 25°C typical Push/pull symmetric; 50 µA typical, 20 µA minimum, 100 µA maximum Turn-on ≤0.1 second
Temp. Compensation Effect @ 0% RH Effect @ 100% RH	True RH = (Sensor RH)/(1.093-.0012T), T in °F True RH = (Sensor RH)/(1.0546-0.00216T), T in °C ±0.007% RH/°C (negligible) −0.22% RH/°C (<1% RH effect typical in occupied space systems above 15°C (59°F))
Humidity Range Operating Storage	 0 to 100% RH, non-condensing[1] 0 to 90% RH, non-condensing
Temperature Range Operating Storage	 −40° to 85°C (−40° to 185°F) −51° to 125°C (−60° to 257°F)
Package[2]	Three pin solderable ceramic SIP
Handling	Static sensitive diode protected to 15 kV maximum

Notes:
1. Extended exposure to ≥90% RH causes a reversible shift of 3% RH.
2. This sensor is light sensitive. For best results, shield the sensor from bright light.

OUTPUT VOLTAGE VS RELATIVE HUMIDITY (at 0°C)



OUTPUT VOLTAGE VS RELATIVE HUMIDITY (at 0°C, 25°C, and 85°C)



Pressure and Force Sensors

Piezoresistive Technology

PIEZORESISTIVE TECHNOLOGY

Background

In the late 1950's, Honeywell's Corporate Technology Center completed basic research on the piezoresistive properties of silicon diffused layers. The first Honeywell application of the piezoresistive device was a solid state accelerometer for the Avionics Division. SSED (Solid State Electronics Division) was formed in the mid-1960's as an internal facility devoted to solid state technology development for application in Honeywell systems. One of the first areas of development was the continued study of piezoresistive properties of silicon layers and development of design criteria.

SSED has been producing piezoresistive transducers since the mid-1960's. The Avionics Division produces a barometric pressure sensor that is used on the Douglas DC-10 as a pressure input to the on-board computer for measuring aircraft altitude in the Digital Air Data System. Pressure sensors have been produced for Honeywell's Process Control Division since 1972, and have been applied over input pressures from less than 1 psig to nearly 10,000 psig.

In 1972, MICRO SWITCH began to investigate piezoresistive device characteristics as a basis for further technology development. From 1972 to 1976, most of the MICRO SWITCH effort was concentrated on working with automobile manufacturers because of the unique and time sensitive opportunities that existed. This experience gave us an excellent base for moving into other markets. Since 1977, MICRO SWITCH has actively pursued the General Sales Markets.

In 1988/89 the fabrication of the piezoresistive sensors for MICRO SWITCH was transferred to its own facility located in Richardson, Texas. This facility now fabricates not only the pressure and force sensors but also a full line of other silicon based sensors including Hall effect, temperature, airflow, optoelectronic and others. This move provided MICRO SWITCH with a complete fabrication process from pure silicon to finished product.

Description

Piezoresistance of a semiconductor can be described as the change in resistance caused by an applied strain of the diaphragm. Thus, solid state resistors can be used as pressure and force sensors, much like wire strain gages, but with several important differences and advantages.

The high sensitivity, or gage factor, is perhaps 100 times that of wire strain gages. Piezoresistors are implanted into a homogeneous single crystalline silicon medium. The implanted resistors are thus integrated into the silicon force sensing member. Typically, other types of strain gages are bonded to force sensing members of dissimilar material, resulting in thermoelastic strain and complex fabrication processes. Most strain gages are inherently unstable due to degradation of the bond, as well as temperature sensitivity and hysteresis caused by the thermoelastic strain.

Silicon is an ideal material for receiving the applied force. Silicon is a perfect crystal and does not become permanently stretched. After being strained, it returns to the original shape. Silicon wafers are better than metal for pressure sensing diaphragms, as silicon has extremely good elasticity within its operating range. Silicon diaphragms normally fail only by rupturing.

PRESSURE SENSING

The sensing element of a MICRO SWITCH solid state pressure or force sensor consists of four nearly identical piezoresistors buried in the surface of a thin circular silicon diaphragm. The thin diaphragm is formed by chemically etching a square cavity into the surface opposite the piezoresistors. The unetched portion of the silicon slice provides a rigid boundary constraint for the diaphragm and a surface mounting to some other member.

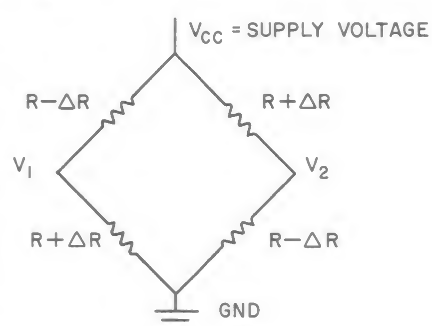
A pressure or force causes the thin diaphragm to flex, inducing a stress or strain in the diaphragm and also in the buried resistors. The resistor values will change depending on the amount of strain they undergo, which depends on the amount of pressure or force applied to the diaphragm. Therefore, a change in pressure (mechanical input) is converted to a change in resistance (electrical output). The sensing element converts (transduces) energy from one form to another.

The resistors can be connected in either a half-bridge or a full Wheatstone bridge arrangement. For a pressure or force applied to the diaphragm using a full bridge arrangement, the resistors can be theoretically approximated as shown in Figure 1 (non-amplified units).

$R \pm \Delta R$ and $R - \Delta R$ represent the actual resistor values at the applied pressure or force. R represents the resistor value for the undeflected diaphragm (P = O) where all four resistors are nearly equal in value. ΔR represents the change in resistance due to an applied pressure or force. All four resistors will change by approximately the same value. Note that two resistors increase and two decrease depending on their orientation with respect to the crystalline direction of the silicon material.

The signal voltage generated by the full bridge arrangement is proportional to the amount of supply voltage (Vcc) and the amount of pressure or force applied which generates the resistance change ΔR.

Figure 1



Pressure Sensors

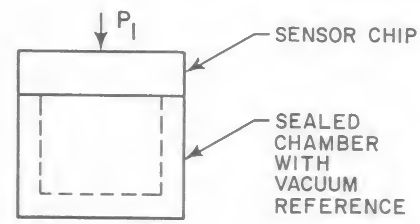
Measurement Types

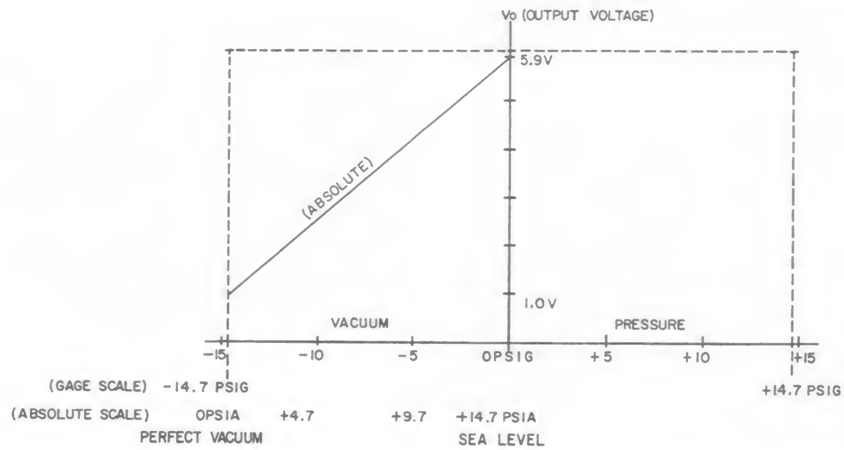
MEASUREMENT TYPES

Absolute pressure is measured with respect to a vacuum reference, an example of which is the measurement of barometer pressure. In absolute devices the P2 port is sealed with a vacuum representing a fixed reference. The difference in pressure between the vacuum reference and the measurand applied at the P1 port causes the deflection of the diaphragm, producing the output voltage change.

Absolute Pressure

Signal conditioned sensor output is shown.
One volt output represents perfect vacuum.

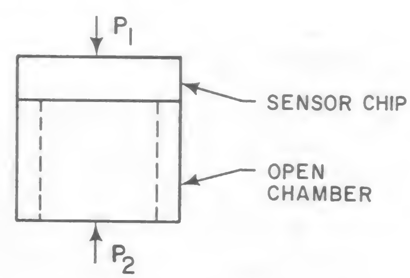


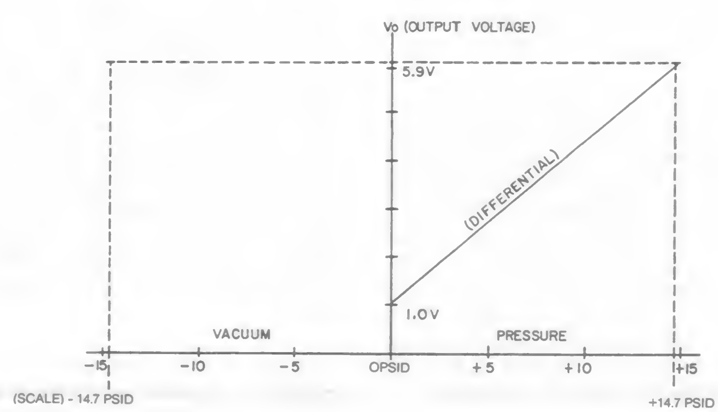


Differential pressure is the difference between two pressures. For instance, the measurement of pressure dropped across an orifice or venturi used to compute flow rate. In differential devices measurands are applied to both ports.

Differential Pressure

Signal conditioned sensor output is shown.
One volt output occurs when pressures are equal on both ports.



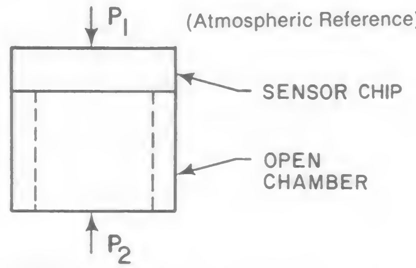


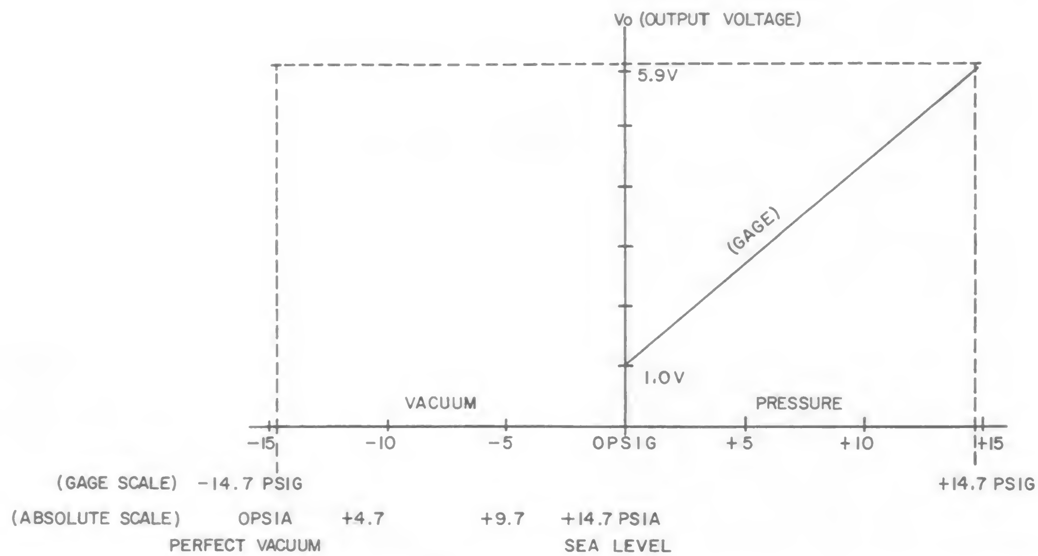
MEASUREMENT TYPES

Gage pressure is a form of differential pressure measurement in which atmospheric pressure is used as the reference. Measurement of auto tire pressure, where a pressure above atmosphere is needed to maintain tire performance characteristics, is an example. In gage devices the P1 port is vented to atmospheric pressure and the measurand is applied to the P2 port.

Gage Pressure

High level sensor output is shown.
One volt output represents ambient pressure.

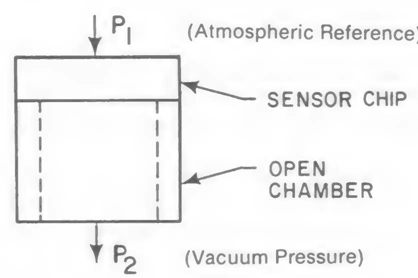


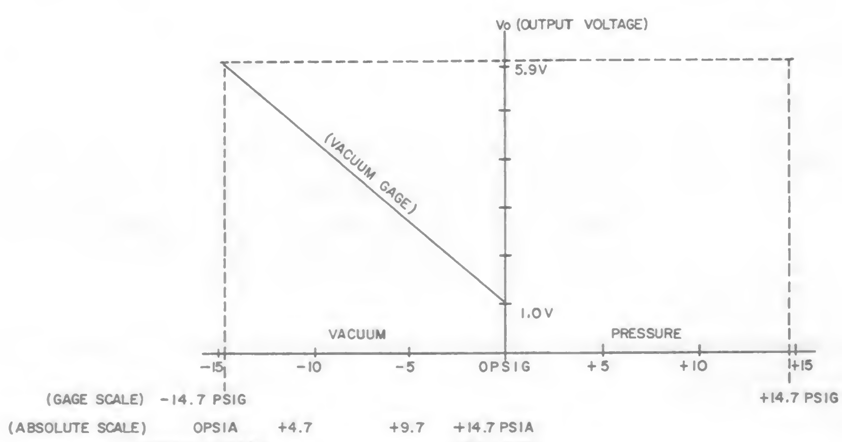


Vacuum Gage pressure is a form of pressure measurement in which vacuum pressures are sensed with reference to ambient pressure.

Vacuum Gage Pressure

High level sensor output is shown.
One volt output represents ambient pressure.





Pressure and Force Sensors

Selection Considerations

COMPATIBILITY
It is very important to insure compatibility between the pressure or force sensor and the application in which it is used. The following should be considered before a sensor selection is made: (1) material; (2) chemicals; (3) concentration; (4) temperature; (5) exposure time; (6) type of exposure; (7) criteria for failure; and (8) general information such as application environment, protection of the device, and other foreign substances in the area.

In all cases, the customer is ultimately responsible for assuring that the device/material is suitable for the application.

ERRORS THAT AFFECT SENSOR PERFORMANCE
When calculating the total error of a pressure or force sensor, the following defined errors should be used. To determine the degree of specific errors for the pressure sensor you have selected, refer to that sensor's specification page in the catalog.

NOTE: In specific customer applications some of the published specifications can be reduced or eliminated. For example, if a sensor is used over half the specified temperature range, then the specified temperature error can be reduced by half. If an auto zeroing technique is used, the null offset and null shift errors can be eliminated.

Null offset is the electrical output present when the pressure or force on both sides of the diaphragm is equal.

Span is the algebraic difference between the output end points. Normally the end points are null and full scale.

Null temperature shift is the change in null resulting from a change in temperature. Null shift is not a predictable error because it can shift up or down from unit to unit. Change in temperature will cause the entire output curve to shift up or down along the voltage axis **(Figure 1).**

Sensitivity temperature shift is the change in sensitivity due to change in temperature. Change in temperature will cause a change in the slope of the sensor output curve **(Figure 2).**

Linearity error is the deviation of the sensor output curve from a specified straight line over a desired pressure range. One method of computing linearity error is least squares, which mathematically provides a best fit straight line (B.F.S.L.) to the data points **(Figure 3).**

Figure 1
Null Shift Error

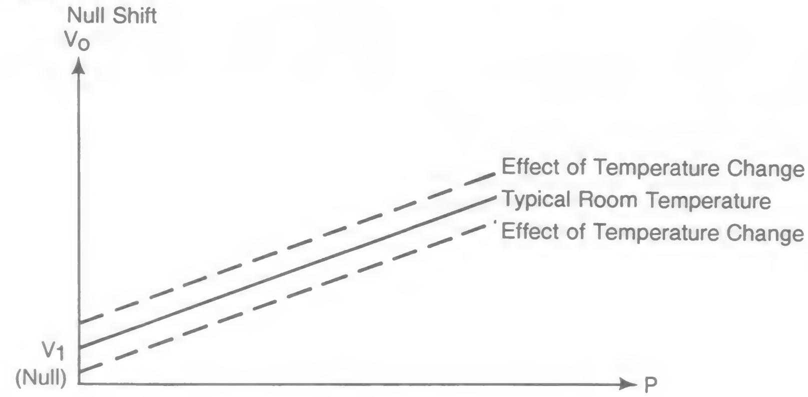


Figure 2
Sensitivity Shift Error

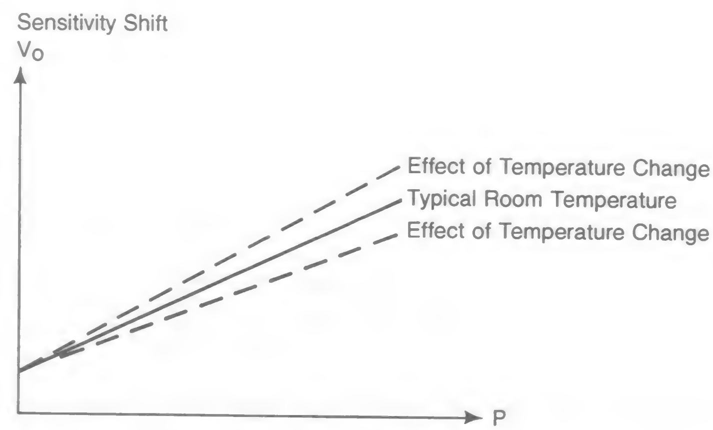


Figure 3
Best Fit Straight Line Linearity

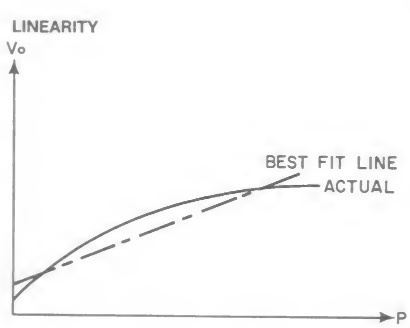
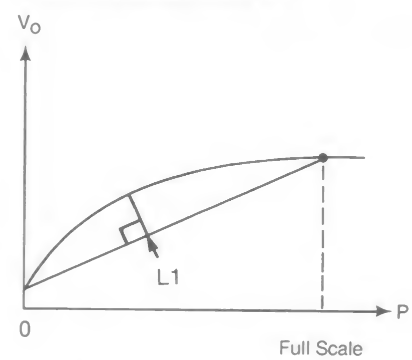


Figure 4
Terminal Base Linearity



Another method is terminal base linearity (T.B.L.) or end point linearity. T.B.L. is determined by drawing a straight line (L1) between the end data points on the output curve. Next draw a perpendicular line from line L1 to a data point on the output curve. The data point is chosen to achieve the maximum length of the perpendicular line. The length of the perpendicular line represents terminal base linearity error **(Figure 4).**

Pressure and Force Sensors

Selection Considerations

Repeatability error is the deviation in output readings for successive applications of any given input pressure or force with other conditions remaining constant **(Figure 5).**

Hysteresis error is usually expressed as a combination of mechanical hysteresis and temperature hysteresis. MICRO SWITCH expresses hysteresis as a combination of the two effects **(Figure 6).**

Mechanical hysteresis is the output deviation at a certain input pressure or force when that input is approached first with increasing pressure or force and then with decreasing pressure or force.

Temperature hysteresis is the output deviation at a certain input, before and after a temperature cycle.

Ratiometricity implies the sensor output is proportional to the supply voltage with other conditions remaining constant. Ratiometricity error is the change in this proportion and is usually expressed as a percent of Span.

CALCULATING ACCURACY OR TOTAL ERROR

When choosing a pressure or force sensor, the total error contribution is important. The following methods take into account the individual errors and the unit-to-unit interchangeability errors.

Two methods for calculating total error are:
Root Sum Square (R.S.S.) using maximum values, and worst case error. R.S.S. method gives the most realistic value for accuracy. With the worst case error method, the chances of one sensor having all errors at the maximum are very remote.

Example

An application requires 0-15 psig, 5° to 50° temperature range, 7VDC supply. A 142PC15G will be used for the example (see 142PC15G specifications on page 37).

1. **Determine error values**

Parameter		**Max. (% Span)**
Null offset	$\frac{.05V}{5V} \times 100\%$	= 1.0%
Span error	$\frac{.05V}{5V} \times 100\%$	= 1.0%
Linearity		0.75%
Combined null/span shift (Calculate at max. and min. application temperature. Use higher of the two numbers)	$\frac{50°C - 25°C}{63°C - 25°C} \times 1\%$ shift	= 0.70%
	$\frac{25°C - 5°C}{25°C - (-18°C)} \times 1\%$ shift	= 0.50%
Repeatability & Hysteresis		0.30%
Stability for 1 year		1.0%
Ratiometricity error		1.0%

2. **Calculate total error**
The R.S.S. method: take the square root of the sum of the squares of the errors determined in Step 1
R.S.S. max. = $\sqrt{1.0^2 + 1.0^2 + 0.75^2 + 0.7^2 + 0.3^2 + 1.0^2 + 1.0^2}$
R.S.S. max. error = 2.3% span max.
Worst Case Error = 1.0 + 1.0 + 0.75 + 0.7 + 0.3 + 1.- + 1.0
Worst Case Error = 5.75% span absolute maximum.

Figure 5
REPEATABILITY

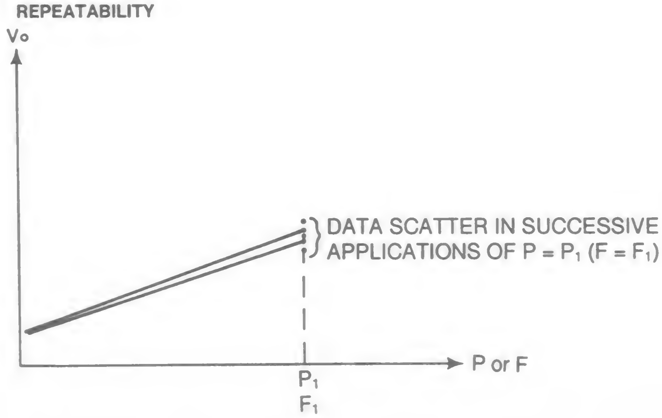
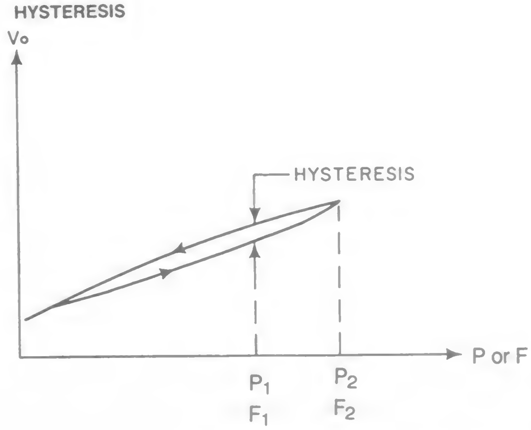


Figure 6
HYSTERESIS



Pressure and Force Sensors

Output Signal Adjustment and Temperature Compensation for 24PC and FS Series – Note #1

INTRODUCTION

Many pressure and force sensor applications require close control over performance parameters such as sensitivity, linearity, hysteresis, and others. Using computer controlled laser trimming on the 140/160PC and 240PC pressure sensors, MICRO SWITCH provides this close control and higher performance than can be achieved using discrete circuitry. Temperature compensation circuitry is an integral part of the device and is optimized on each unit as part of the calibration procedure. Null offset and Span are similarly controlled. No adjustment or recalibration by the user is required.

26 and 176PC sensors provide interchangeability from unit to unit and provide other limited temperature compensation. The 26 and 176PC are voltage excited.

The 24PC and FS feature a wider tolerance on null offset and Span and do not include temperature compensation. The following procedures can be used to set the null offset and Span to desired output values (0-100 mV typically) and to compensate for temperature shift.

OUTPUT SIGNAL ADJUSTMENT

Setting Null Offset to Zero

1. Measure null offset (lead 2 to 4).
2. For a negative null offset place a resistor from lead 1 (supply) to lead 2 (positive output). Expect values around 300K ohms **(Figure 1A).**
3. For a positive null offset place a resistor from lead 1 (supply) to lead 4 (negative output). Expect values around 300K ohms **(Figure 1B).**

Setting Span

1. Measure the bridge resistance (R_B) from lead 2 to 4 (output).
2. Measure Span.
3. Calculate a shunt resistor (R_S) using the following equation:

$$R_S = \frac{R_B}{\frac{K_M}{K_D} - 1}$$

Where:
K_M = measured Span
K_D = desired Span
Generally: $5K < R_S < 20K$ ohms

4. Install shunt resistor from lead 2 to 4 (output) as in **Figure 2.**

Figure 1A
If null offset is negative

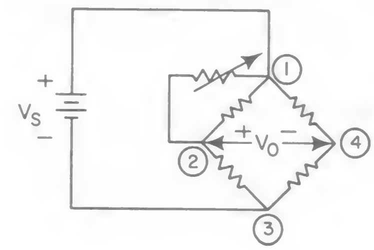


Figure 1B
If null offset is positive

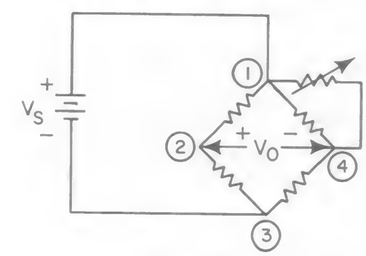
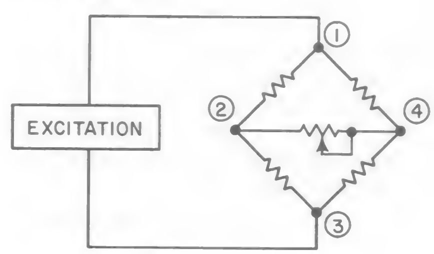


Figure 2
Setting Span



TEMPERATURE COMPENSATION[1]

Introduction

The 24PC pressure and FS force sensors exhibit the following effects as temperature increases:

1. Pressure or force sensitivity decreases.[2]
2. The resistance of each piezoresistor increases.[2]

For illustration, consider the following piezoresistor model:

$R(P,T) = C_T(R_o + C_p k(25°C)P)$

Where:

R(P,T) is the value of the piezoresistance (ohm)

R_o is the unstressed (ambient) piezoresistance at 25°C

R_o $= R(P = O, T = 25°C)$

C_T is the change in R(P,T) with temperature.

$$C_T = \frac{R(P = O, T)}{R_o} \left(\frac{ohm}{ohm}\right)$$

k(25°C) is the pressure or force sensitivity at 25°C

$$\mathbf{k(25°C)} = \frac{R(P, 25°C) + R_o}{P} \left(\frac{ohm}{psi\ or\ g}\right)$$

k(T) is the pressure or force sensitivity at applied temperature.

C_p is the change in pressure or force sensitivity with temperature.

$$C_p = \frac{k(T)}{k(25°C)} \quad \frac{ohm/psi\ or\ g}{ohm/psi\ or\ g}$$

P is the applied pressure (psi)

F is the applied force (g)

Nominal C_p and C_T characteristics are given in **Figure 3.**

Method #1

The circuit of **Figure 4** provides temperature compensation by combining a current source and positive feedback. Essentially, the change in C_T is partially cancelled by an opposite change in C_p.

For a different supply voltage, vary the 24.9K resistor. Make sure that the common mode input voltage and output voltage swing limitations of the amplifiers are not exceeded.

24PC sensors are less sensitive to temperature when current excited. We strongly urge that current excitation be considered as a means of minimizing errors due to temperature changes. Feel free to contact the application center to get an update on this subject.

Figure 3
24PC Nominal Piezoresistor Characteristics

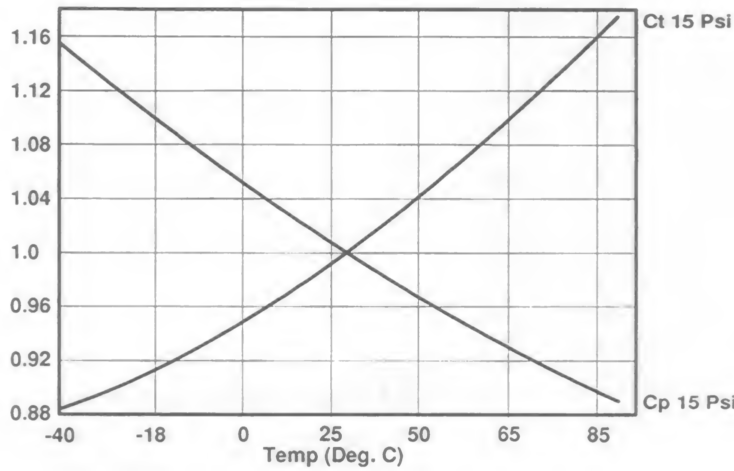
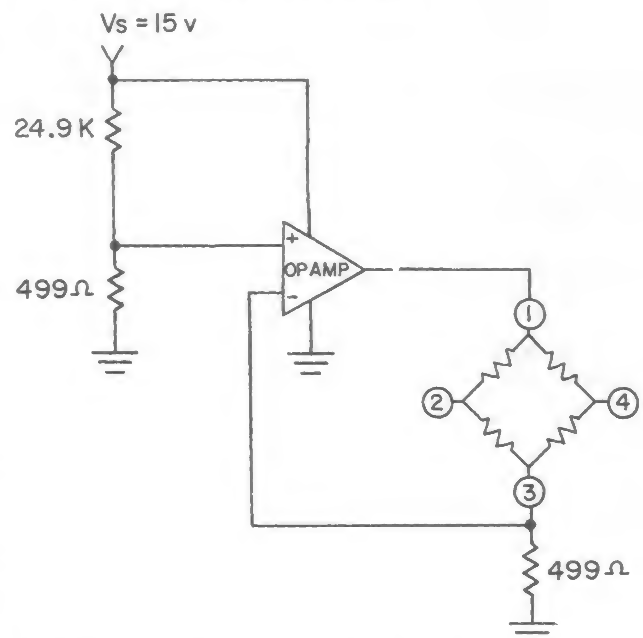


Figure 4
Temperature Compensation Method #1

Recommended Op Amps:
LM358—Dual Op Amp
LM124—Quad, military grade Op Amp



[1] Temperature Compensation Methods #1-2 affect the **sensitivity** of the sensor, not the null offset, in that the change in the slope of the output curve caused by temperature is minimized.
[2] Consistent from unit to unit within a narrow tolerance.

Pressure and Force Sensors

Output Signal Adjustment and Temperature Compensation for 24PC and FS Series – Note #1

Method #2

C_p is inversely proportional to temperature. To compensate for this effect, the voltage applied to the sensor bridge must be proportional to temperature. One approach is to connect a thermistor with a negative temperature coefficient (resistance decreases with temperature) in series with the bridge, as shown in **Figure 5A.** Thermistors with the exact resistance vs. temperature characteristics to compensate the bridge may not be readily available. An alternate approach is the use of a thermistor-resistor network to meet the required characteristics. Standard 1% resistor values (with a standard thermistor) are shown in **Figure 5B.** This method provides temperature compensation to within ±2% Span over the range of −10° to 50°C. The thermistor should be located close to the sensor, so they will experience the same thermal environment.

TEMPERATURE COMPENSATION TO CONTROL SHIFT OF NULL OFFSET

Null shift caused by temperature can be compensated using the circuit in **Figure 6.** However, it is required that the sensor first have sensitivity temperature compensation. In other words, you must use a 26 and 176 or a 24PC or FS employing one of Methods 1 or 2.

Null shift with temperature is unpredictable; therefore the sensors must be compensated individually.

1. Measure $V_{2\text{-}3}$ and $V_{2\text{-}4}$ at null over the temperature range of interest (room temperature (T_R), and some other temperature (T)).
2. Measure $R_{2\text{-}3}$ at room temperature.
3. Select R_1 for $V_n = V_{2\text{-}3}$ at room temperature.
4. Calculate the value of R_2 necessary to compensate the measured null shift.

$$R_2 = R_{2\text{-}3}\left[\frac{V_{2\text{-}3(T)} - V_{2\text{-}3\,(T_R)}}{V_{2\text{-}4(T)} - V_{2\text{-}4\,(T_R)}}\right]$$

5. Connect R_2 to terminal 2 if $V_{2\text{-}4(T)} - V_{2\text{-}4(T_R)}$ is positive. Connect it to terminal 4 if negative.

Figure 5
Temp. Comp. Method #2

Figure 5A

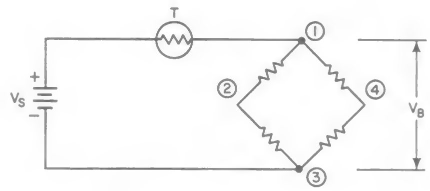
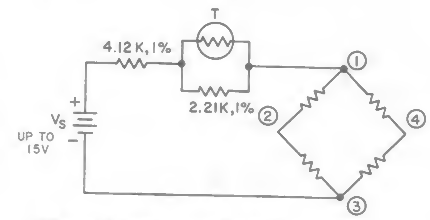


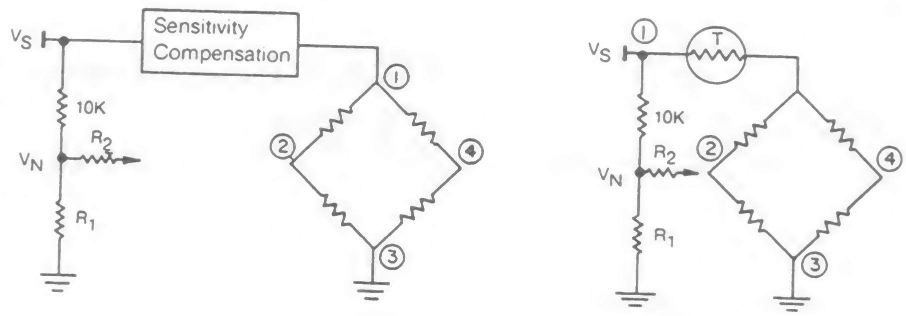
Figure 5B
Dale Thermistor 2M1501* or equivalent



***Dale Electronics, Inc.**
North Fork, NB

Figure 6
Null Temperature Compensation

(A) Customer supplied temperature compensation
(B) Built-in temperature compensation



Pressure and Force Sensors

Bridge Amplifiers for 20/170PC and FS Series – Note #2

INTRODUCTION
Two circuits are shown here which can be used to amplify the millivolt output of the 20/170PC and FS Series. **Only high input impedance amplifiers should be used with MICRO SWITCH pressure and force sensors.**

Figure 1
This circuit employs one amplifier with a low input current offset (such as an LM108) permitting large value input resistors. To change gain, R_3 and R_4 are adjusted while maintaining impedance matching.

Figure 2
Placing all of the gain in the first stage (three amplifiers) makes this circuit less susceptible to common mode errors. The second stage (one amplifier) should be used as a unity gain summing amplifier.

NOTE: MICRO SWITCH recommends that amplification does not exceed 250 times. Reverse pins 2 and 4 when using an absolute sensor.

Figure 1
$V_o = (V_2 - V_4)\ R_3/R_1$ for $R_3/R_1 = R_4/R_2$

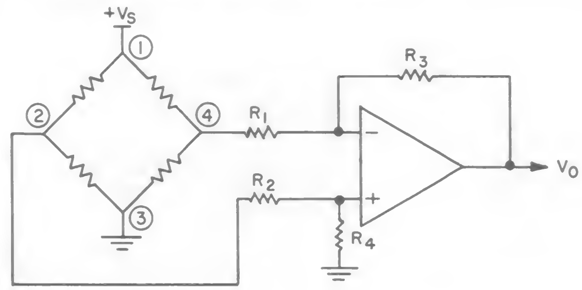
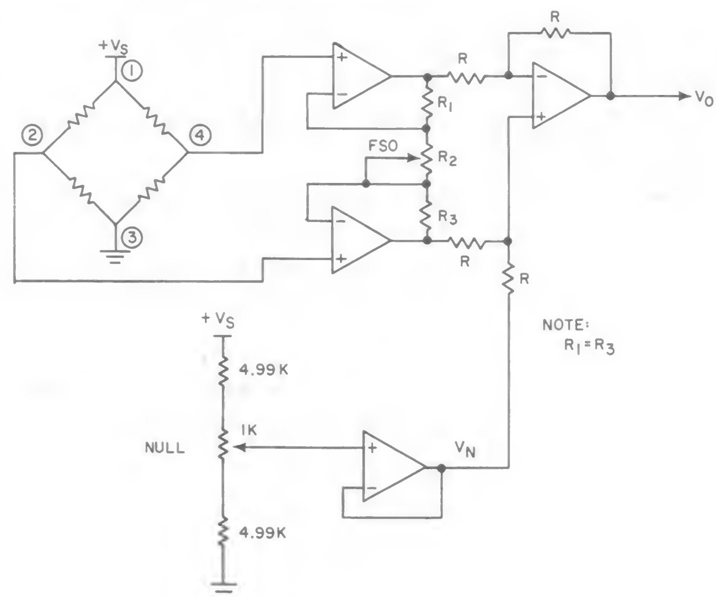


Figure 2
$V_o = (V_2 - V_4)\ (1 + 2R_1/R_2) + V_n$, Note: $R_1 = R_3$



Pressure and Force Sensors

Output Scaling of the 140*/160/180 and 240PC* Series – Note #3

INTRODUCTION

The standard 1-6 VDC output signal of the 140/160/180 and 240PC* Series can be altered (scaled) using one of the following procedures:

SUPPLY VOLTAGE

All 140/160/180 and 240PC* sensors are considered ratiometric meaning the output signal is proportional to the supply voltage **(Figure 1).** Standard output characteristics specified by MICRO SWITCH in product literature imply an 8 VDC supply voltage. Changing that supply (V_s) has the following effect:

Null Offset (V) $= \frac{1}{8} V_s$

Span (V) $= \frac{5}{8} V_s$

The ratiometricity error associated with this method is specified in the General Specifications sections of this catalog.

MICRO SWITCH recommends that supply voltage be within the range of 7 VDC to 12 VDC for 140PC, 180PC, 240PC and 6 VDC to 12 VDC for 160PC.

DUAL SUPPLY VOLTAGE

The general transfer function for 140*/160/180 and 240PC* Series that relates input pressure (P) to output voltage (V_o) is:

$V_o = (V_{cc} - V_{ss})(k_o + k_1 P) + V_{ss}$ **(Figure 2)**

Where:

V_{cc} = supply voltage to V_s (V)

V_{ss} = supply return voltage (V)

k_o = null offset factor

$$\frac{\text{nominal null offset voltage}}{\text{nominal supply voltage}} \left(\frac{V}{V}\right)$$

k_1 = sensitivity factor

$$\frac{\text{nominal Span}}{(\text{nominal supply voltage}) \times (\text{full scale pressure})} \left(\frac{V}{V \times psi}\right)$$

P = applied pressure (psi)

EXAMPLE:

Desired output is $V_o = 0V$ at null ($P = 0$) and $V_o = 10V$ at full pressure. Solving for V_{cc} with $V_o = 0V$ at null we obtain:

$0 = (V_{cc} - V_{ss})(k_o + k_1(0)) + V_{ss}$

$0 = (V_{cc} k_o - V_{ss} k_o + V_{ss})$

$V_{cc} = V_{ss}(1 - 1/k_o)$

$k_o = \frac{1v}{8v} = \frac{1}{8}$ for standard 140/160/180 and 240PC

$V_{cc} = V_{ss}(-7)$

We have obtained the first of two equations with two unknowns:

1. $V_{cc} = -7 V_{ss}$ (V)

Solving for V_{cc} with $V_o = 10v$ at $P =$ full scale pressure we obtain:

$10v = (V_{cc} - V_{ss})(k_o + k_1(FSP)) + V_{ss}$

$k_o = \frac{1}{8}$

$k_1 = \frac{5v}{8v \times FSP}$ for standard 140PC, 160PC/180PC, 240PC

$10_v = (V_{cc} - V_{ss})(1/8 + 5/8) + V_{ss}$

$10v = \frac{3 V_{cc}}{4} + \frac{V_{ss}}{4}$

$40v = 3 V_{cc} + V_{ss}$

2. $V_{cc} = \frac{40 - V_{ss}}{3}$

We now have two equations (1 and 2) and two unknowns and therefore can solve for V_{cc} and V_{ss}:

$V_{cc} = -7 V_{ss} = \frac{40}{3} - \frac{V_{ss}}{3}$

$\frac{-20}{3} V_{ss} = \frac{40}{3}$

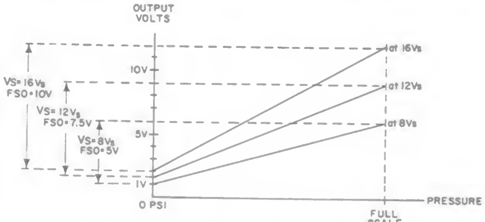
$V_{ss} = -2$ VDC

$V_{cc} = 14$ VDC

For a Span of 0-10 VDC set $V_{cc} = 14$ VDC, $V_{ss} = -2$ VDC.

Figure 1

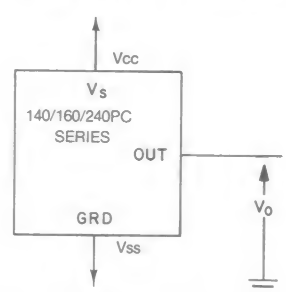
Output scaling of the 140*/160/180 and 240PC* Series By Supply Voltage



* Does not include 249PC, 142PC01G and 142PC01D.

Figure 2

Scaling By Dual Power Supply



Pressure and Force Sensors

Output Scaling of the 140*/160/180 and 240PC* Series – Note #3

EXTERNAL SCALING CIRCUIT

The circuit in **Figure 3** allows independent adjustment of null offset and span of the 140*/160 and 240PC* Series. The first stage adds an offset voltage to the sensor output — the value of that offset voltage is determined by potentiometer R_3. Span (and sensitivity) are adjusted by potentiometer R_5 of the second stage.

SPECIAL LASER TRIMMING

A wide range of output scaling may be achieved through the combination of laser trimming and modification of the thick film circuit. MICRO SWITCH will be pleased to quote on scaling to satisfy your requirements.

* Does not include 249PC.

1. The output of the sensor in Figure 3 (V_1) is given by:
   $V_1 = V_s(k_o + k_1P)$

Where:

V_s = supply voltage (V)

k_o = null offset factor $\dfrac{\text{nominal null offset voltage}}{\text{nominal supply voltage}} \left(\dfrac{V}{V}\right)$

k_1 = sensitivity factor $\dfrac{\text{nominal Span}}{\text{(nominal supply voltage)} \times \text{(full scale pressure)}} \left(\dfrac{V}{V \times psi}\right)$

P = applied pressure (psi)

2. The output of the first stage (V_2) is given by:
   $V_2 = -V_1\,(R_2/R_1) - ((-V_S)\,R_2/R_3)$

3. The output of the second stage (V_o) is given by:
   $V_o = -V_2(R_5/R_4)$

Combining equations #1, 2, and 3 we can express the circuit output (V_o) in terms of the supply voltage (V_s) and variable resistors R_3 and R_5.

$$\begin{aligned} V_o &= -V_2(R_5/R_4) \\ &= [(V_1(R_2/R_1) - V_s(R_2/R_3)]\,(R_5/R_4) \\ &= [(V_s(k_o + k_1P)\,(R_2/R_1) - V_s(R_2/R_3)]\,(R_5/R_4) \\ &= V_s\,(R_5/R_4)\,[(k_o + k_1P)\,(R_2/R_1) - R_2/R_3] \end{aligned}$$

EXAMPLE:

Desired output is 0 VDC at 0 psi (null) and 5 VDC at full scale pressure (FSP)

$V_o = V_s(R_5/R_4)\,[(k_o + k_1P)\,(R_2/R_1) - R_2/R_3]$

$k_o = \dfrac{1}{8}$

For standard 140*/160/180 and 240PC*

$k_1 = \dfrac{5}{8 \times FSP}$

Assume: V_s = 8 VDC, $R_1 = R_2 = R_4$ = 10 K ohm

Then:

$$V_o = 8\frac{R_5}{10_k}\left(\frac{1}{8} + \frac{5}{8 \times FSP} \times P\right)(1) - \frac{10_k}{R_3}$$

a) at P = Ø, desired V_o = 0:

$$0 = 8 \times \frac{R_5}{10_k}\left(\frac{1}{8} - \frac{10_k}{R_3}\right)$$

$R_5/10_k = 8\,R_5/R_3$

and since R_5 does not equal zero

R_3 = 80K ohm

b) at P = FSP, desired V_o = 5 VDC:

$$5 = 8\left(\frac{R_5}{10_k}\right)\left[\left(\frac{1}{8} + \frac{5}{8}\right)(1) - \frac{R_2}{R_3}\right]$$

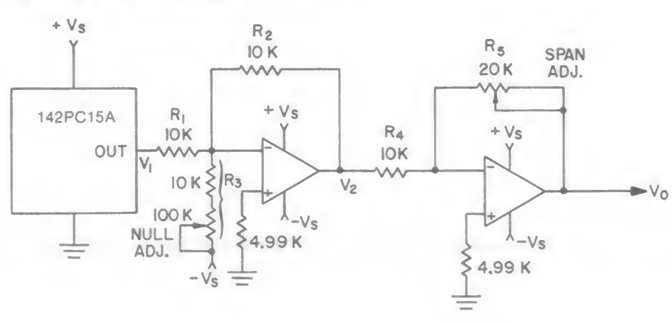
R_3 = 80K, R_2 = 10K

5 = (6-1) (R_5/10K)

R_5 = 10K ohm

For a Span of 0-5 VDC set R_3 = 80K ohm and R_5 = 10K ohm

Figure 3
Scaling By External Circuitry



Reference/Index

Pressure and Force Sensors

40PC Hose and Tubing Recommendations – Note #4

HOSE APPLICATIONS

An alternative to manifold mounting the 40PC pressure sensor is to use a hose in fuel pressure applications. Using a hose to make the pressure connection permits the sensor to be mounted away from the actual sensing location that might be hazardous and difficult to access. Many types of hoses with differing media compatibilities, material compositions, wall thicknesses, working temperatures, working pressures and hose flexibility are available. A 1/16″ ID or 3/32″ ID flexible hose can be used with the 40PC sensor. If a hose that is less flexible such as FEP is used, 3/32″ ID may be more appropriate. Contact the hose manufacturer regarding the suitability of a particular hose for an application.

Clamps, as noted below, are recommended with specific tubing. It is up to the user to determine if the application warrants their usage. Many types of hose/tubing are available, including Silicone, Tygon, Urethane, Nylon, FEP, and Vinyl.

HOSE AND TUBING SPECIFICATIONS

Vinyl hose, which is typically used as a general purpose lab hose, is very flexible and inexpensive. Vinyl tubing is best at room temperatures and under 40 psig. The specifications for vinyl hose from Cole-Parmer are:

Hose	Wall Thickness/ID	Max. Press. @ 21°C (70°F)	Max. Temp (°C/°F)
Vinyl (Cole-Parmer Cat. # E-06405-01)	1/32″ by 1/16″	40 psi	82/180

Silicone tubing is flexible and suitable for general purpose use. Silicone tubing offers better temperature and chemical resistance than vinyl in most environments. Silicone tubing is recommended at pressures less than 15 psig. The specifications for silicone tubing from Cole-Parmer are:

Tubing	Wall Thickness/ID	Max. Press. @ 21°C (70°F)	Max. Temp (°C/°F)
Silicone (Cole-Parmer Cat. # E-06411-62)	1/32″ by 1/16″	15 psi	238/460

Tygon tubing, recommended for pressures less than 50 psig, is a more durable general purpose tubing. It is slightly more expensive than vinyl. The specifications for Tygon tubing from Cole-Parmer are:

Tubing	Wall Thickness/ID	Max. Press. @ 21°C (70°F)	Max. Temp (°C/°F)
Tygon (Cole-Parmer Cat. # E-06408-62)	1/32″ by 1/16″	50 psi	74/165
Tygon (Cole-Parmer Cat. # E-06408-63)	1/32″ by 3/32″	40 psi	74/165

Urethane tubing can be used at higher temperatures and pressures but it is more expensive than vinyl, silicone or Tygon. Urethane tubing is flexible and strong. Specifications for Urethane "Superthane" tubing, available from Newage Industries, are:

Tubing	Wall Thickness/ID	Max. Press. @ 21°C (70°F)	Max. Temp (°C/°F)
Superthane (Part # 210 0070-100)	1/32″ by 1/16″	134 psi	93/200

FEP (Fluoropolymer) is a semi-flexible tubing that offers excellent temperature, pressure and chemical resistance. However, this tubing is "semi-flexible," and much more rigid than Tygon, or vinyl. When used for applications as described in this note, it is recommended that FEP 3/32″ ID tubing be used with a clamp. Specifications for FEP tubing, available from Cole-Parmer, are:

Tubing	Wall Thickness/ID	Max. Press. @ 21°C (70°F)	Max. Temp (°C/°F)
FEP (Cole-Parmer Cat. # E-06406-63)	1/32″ by 1/16″	350 psi	205/400

Nylon 11 tubing (flexible grade) has excellent strength and chemical resistance. This tubing is not as flexible as Tygon, or vinyl, and is more expensive. When used for applications as described in this note, it is recommended that Nylon 11 3/32″ ID tubing be used with a clamp. The specifications for Nylon 11 tubing, available from Freelin-Wade, are:

Tubing	Tubing ID	Max. Press. @ 24°C (75°F)	Max. Temp (°C/°F)
Nylon 11 (1J-200-)	3/32″	225 psi	93/200

Pressure and Force Sensors

40PC Hose and Tubing Recommendations – Note #4

HOSE CLAMPS

Hose clamps are recommended for use with all of the hoses listed. In addition to helping prevent leakage and loosening, hose clamps provide a stronger connection to the sensor port. Clamps that are recommended for use in applications described in this paper are the Oetiker Two-Ear Clamp and the Oetiker One-Ear Special Clamp from Newage Industries.

Clamp	Nom. OD (In.)	Inches Open-Closed
Oetiker Two Ear Clamp (Oetiker Part # 0041R) (Newage Ind. Part # 582 2670)	5/32	.161-.122
Oetiker One Ear Special Clamp (Oetiker Part # 4.1R) (Newage Ind. Part # 582 0920)	5/32	.161-.130

SUPPLIER LIST

Cole-Parmer Instrument Company
625 East Bunker Court
Vernon Hills, Illinois 60061-1844 U.S.A.
(800) 323-4340

Newage Industries Plastics Division
2300 Maryland Road
Willow Grove, PA 19090
(215) 657-3151
(FAX) (215) 657-6594
Telex 263780

Freelin-Wade
1730 Miller Street
P.O. Box 1007
McMinnville, OR 97128
(503) 434-5561
(FAX) (503) 472-1989

Pressure and Force Sensors

40PC Building Block Manifold Mount Application – Note #5

HEATING EFFECTS ON SEALING INTERFACE

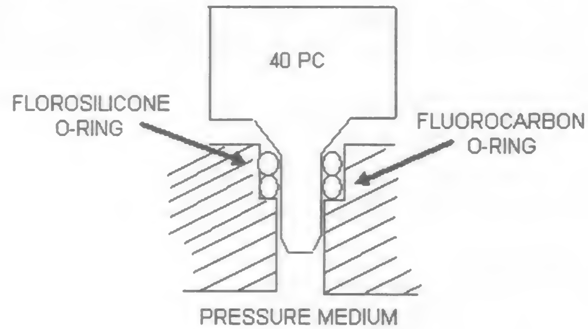
Careful consideration must be given to the design of the sealing interface between the second level package and the 40PC. Specifically, care must be taken to select a seal material that will withstand the specified temperature extremes while maintaining sealing capabilities when exposed to the application's pressure media. In the past, finding a seal material that satisfied these two requirements had been extremely difficult. One approach is the use of two O-rings, each made of a different material, placed in series. In this approach, one material has exceptional sealing capabilities within the specified temperature range and the other material provides resistance against the pressure media.

FUEL PRESSURE APPLICATIONS

For example, in an automotive fuel pressure application where temperature ranges are often specified at −50°C to 150°C, a fluorosilicone O-ring may be used. The fluorosilicone material provides superior sealing performance at this temperature range, especially at the lower temperatures. However, it will not maintain its sealing when exposed to automotive fuels. A fluorocarbon O-ring provides excellent resistance to automotive fuels, aliphatic hydrocarbons, and aromatic hydrocarbons, but it does not possess the low temperature sealing capabilities of fluorosilicone. While each material alone will not meet the sealing requirements of this application individually, assembling two O-rings, one of fluorosilicone and one of fluorocarbon provides both temperature and pressure media sealing performance.

The O-ring materials are important to the sealing performance of the second level package. The order in which they are assembled in relation to the pressure medium is also important. The O-ring that is resistant to the pressure medium should be placed first, closest to the medium. Referring back to the automotive fuel pressure example, the fluorocarbon O-ring should be closest to the pressure medium. See Figure 1.

Figure 1. Fluorosilicone, fluorocarbon O-ring sealing



The intended sealing of the 40PC is a radial seal along the surface of the small diameter of the stainless steel port, before the taper feature of the large diameter. Using the small diameter as the sealing surface provides a large radial surface for both O-rings to seal against, and accommodates the extra room needed when the O-rings are squeezed upon assembly. The second level O-ring pocket should be designed to yield a minimum and maximum O-ring squeeze of about 16 to 30% respectively, to ensure proper sealing.

Place the O-rings into the second level O-ring pocket. Then insert the 40PC port into the O-rings. Proper position of the O-rings on the port and their position in the pocket are better controlled. Care should be taken not to tear or rip the O-rings with the 40PC port tip during assembly. Even the slightest damage can result in a insufficient seal and cause a failure. A polytetrafluoroethylene coating may be applied to the O-rings before assembly to create a slippery surface that will aid the insertion of the port into the O-rings.

Pressure and Force Sensors

40PC Building Block 2nd Level Design Consideration – Note #6

I. VENTING

The 40PC gage pressure sensing device is a building block that measures the difference between a pressure source and the atmosphere. Measuring atmospheric pressure requires an unobstructed passage to the open environment. The design of a 40PC second level package provides a passage that vents the inside of the package to atmosphere. The second level package incorporates a filter that keeps environmental moisture from entering the sensor. Moisture accelerates the effects of corrosion, shorting, or material deterioration, ultimately degrading sensor performance.

The 40PC filter material is polytetrafluoroethylene (PTFE). PTFE exhibits outstanding chemical inertness. The material has a wide operating temperature range and hydrophobic properties. PTFE allows the passage of gases, but repels water. The PTFE "patch" is thermally bonded onto a plastic base. This patch covers the exit hole of a passage that vents the interior of the second level package to atmosphere. (See Figures 1 and 2).

The degree to which a fluid is repelled from a polymeric material is a function of the pore size and surface free energy of the polymer. If the polymer has a low surface free energy, it will be non-wettable by high surface tension fluids such as water. PTFE is a fluorocarbon resin that has 100% of its backbone carbon atoms fully bonded to fluorine atoms. This fluorine distribution makes PTFE non-polar. PTFE exhibits a low surface energy, the lowest surface free energy of any polymeric materials. Thus, PTFE is ideally suited in a hydrophobic filter application.

Typically, in a pressure sensing application one might expect to have PTFE characteristics of 1 micron pore size, 80% pore rate and a 100 micrometer thickness. A material with these physical characteristics can be expected to have a 0.24 L/min/cm^2 air flow rate at 0.142 psi, 0.95 L/min/cm^2 at 0.711 psi, 1.7 L/min/cm^2 at 1.422 psi and 6.8 L/min/cm^2 air flow rate at 7.112 psi. Water burst pressures will be 15.65 psi (1.1 kgf/cm^2) when applied gradually, and 7.54 psi (0.53 kgf/cm^2) when applied suddenly. All of the above numbers are performance generalizations. Consult the manufacturer for accurate characteristics of the specific PTFE material chosen.

A method of securing the filter to a plastic base is through a thermal weld. Optimal thermal welding parameters to produce the most robust weld are determined empirically. Thermal welding machines, temperature controllers and environmental conditions are a few of the variables that affect welding parameters. The following guidelines may be used as a starting point for experiments to find the most desirable weld parameters.

1. The initial temperature setting of the thermal welder should be at the melt temperature to which the filter will be welded. The temperature should be increased gradually and the welds evaluated for strength.

2. The initial pressure setting of the thermal welder should be set as low as possible to avoid smashing the polymer instead of melting it. The pressure should be increased gradually and the welds evaluated for strength.

Figure 1. Hydrophobic Filter Implementation Example

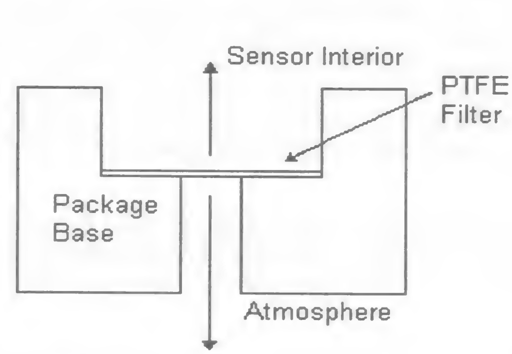
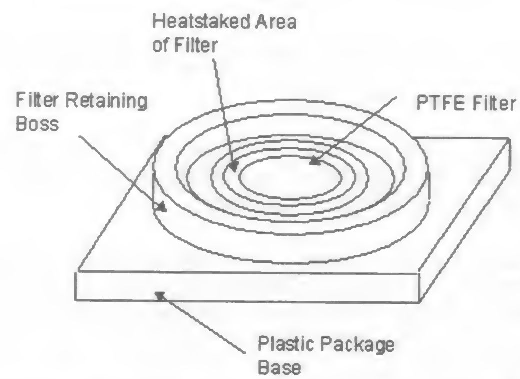


Figure 2. Heatstaking Installation



3. The initial dwell time of the weld tip should be set long enough to allow the melted polymer to flow into the PTFE and secure it. The dwell time depends highly on the temperature that is being used.

Generally, the thermal welding temperature should not exceed 300°C (572°F). Higher temperatures can degrade the PTFE material resulting in poor weld strength and decreased filter properties. Filters welded at temperatures exceeding 300°C should be thoroughly tested and the implications of results on product performance must be fully understood.

II. CIRCUIT PROTECTION

The 40PC is a high performance pressure sensor. In order to obtain the highest performance of the 40PC, serious attention must be given to the overpackage design so that the 40PC receives the best possible circuitry protection. Without proper protection, sensor performance will be diminished or disabled. Electromagnetic Interference (EMI) and Electrostatic Discharge (ESD) are two important factors to consider when designing the proper overpackage for the 40PC.

Electrostatic discharge is the transfer of electrostatic charge between materials at different electrostatic potentials. This condition results from direct contact or an exposure to an electrostatic field. Electrostatic charges are generated by the sliding, rubbing, or separation of materials.

40PC Building Block 2nd Level Design Consideration – Note #6

Electrostatic charges are generated by contact or touch, ordinary plastics, synthetic textile garments, and many common materials. Electrostatic discharge is the transfer of electrostatic charge between materials at different electrostatic potentials. This condition results from direct contact or an exposure to an electrostatic field. Electrostatic charges are generated by the sliding, rubbing, or separation of materials; by contact or touch, ordinary plastics, synthetic textile garments, and many common materials.

Not all components and assemblies are ESD sensitive to the same degree, so different classes have been distinguished to allow a standard ESD sensitivity rating to be used in ESD classification.

Class 1: Components and assemblies that are very sensitive to ESD induced degradation where the worst case voltage sensitivity is between 0 and 1000 volts.

Class 2: Components and assemblies that are sensitive to ESD induced degradation where the worst case voltage sensitivity is between 1000 and 4000 volts.

Class 3: Components and assemblies that are less sensitive to ESD induced degradation where the worst case voltage sensitivity is between 4000 and 15000 volts.

The 40PC is a Class 1 device. It needs special overpackaging to prevent damaging voltage potentials. All ESD control elements applicable to Class 1 devices should be established and exercised throughout the entire assembly process. For a complete specification on ESD control requirements, refer to DOD-STD-1686 and DOD-HDBK-263. This environment should include grounded work stations, grounded floor mats, wrist or heel straps, conductive trays, carriers, and bags. While required ESD handling controls can ensure a safe assembly process on the factory floor, the sensor is unprotected in the field. One method of field protection is the use of diodes placed on a printed circuit board that electrically interfaces with the 40PC.

In this example, a Zener diode such as a Motorola BZX84C20LT1 and a dual switching diode such as a Motorola BAV99 are surface mounted onto a printed circuit board. This circuit board also has holes for connector termination and mounting and termination holes for the 40 PC. See Figure 3.

Once these components are surface mounted, the 40PC is inserted in the PCB assembly. During this assembly process when the 40PC is being handled, the sensor is most vulnerable to ESD damage. After insertion, the 40PC terminals are soldered to complete a 40PC subassembly rated as a Class 3 ESD device. See Figures 4 and 5.

Figure 3. PCB Assembly

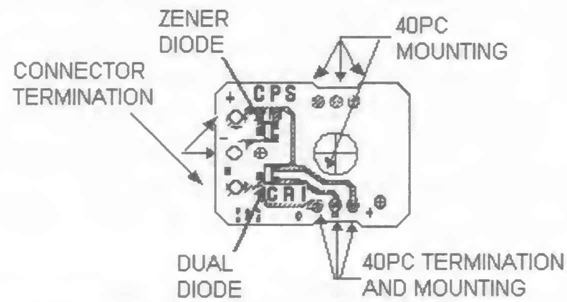


Figure 4. Top View 40PC Subassembly

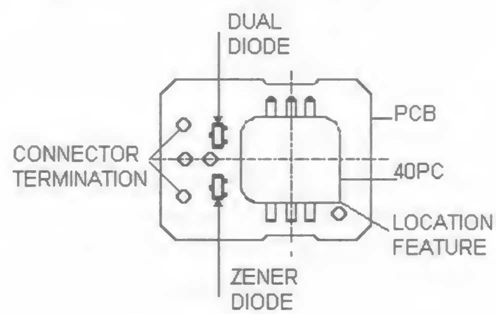
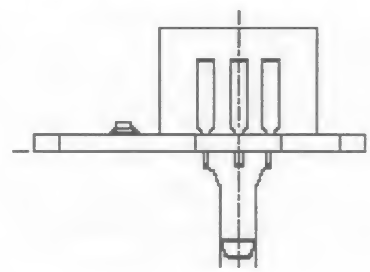


Figure 5. Side View 40PC Subassembly



III. EMI SHIELDING

As the use of electrical/electronic products become increasingly widespread, and devices become smaller and more sophisticated, electromagnetic interference has become a major issue and will become even more so in the future. An electronic device should neither be affected by external noise or be a source of noise to the environment, thereby compromising its own performance or that of another. EMI situations arise from power lines, walkie talkies, cell phones, aircraft and telecommunications.

Pressure and Force Sensors

40PC Building Block 2nd Level Design Consideration – Note #6

Typically, a variation of a "Faraday Cage" can be used to suppress radiated EMI susceptibility. This five sided cage, in conjunction with a printed circuit board with a full ground plane, encloses the 40PC, shielding it from EMI.

This shield may be stamped out of tin clad cold rolled steel with sides formed up to create the sides of the shield (See Figures 6a, 6b, and 7). A lip on the shield provides the interface from the connector terminals to the printed circuit board and also properly grounds the device.

Figure 6a. Wiring Diagram

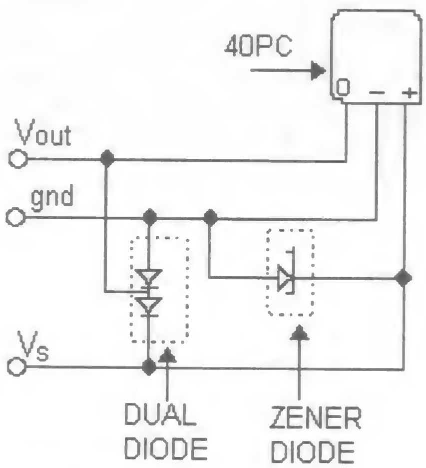


Figure 6b. Shield Blank

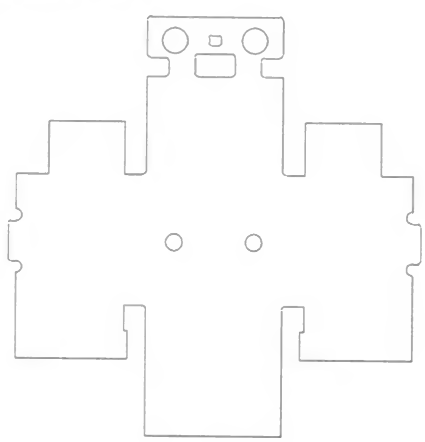
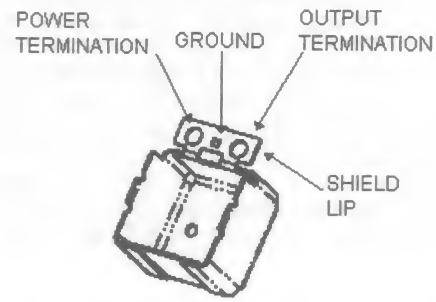


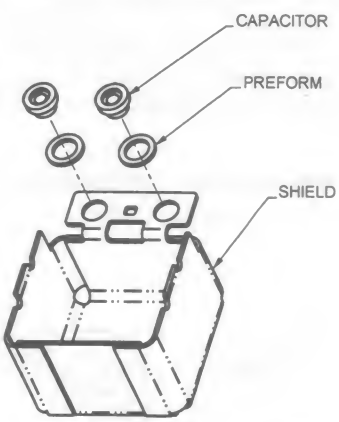
Figure 7. Formed Shield (before forming)



Feedthrough ceramic dielectric capacitors such as Murata DF430-OSS332GMV50 with a capacitance value of 3300 pF +200% −0, and a 50 VDC working voltage, can be used on the shield to provide additional protection against conducted EMI. Any high frequency interference conducted through the wire harness, through the connector and into the sensor is filtered by the capacitors and shorted to ground, keeping the sensor signal clean. See Figure 8.

These capacitors can be placed in the supply and output holes of the shield lip, on top of an SN 96.5 AG 3.5 hard solder preform (with kester "44" RA rosin flux.) The shield assembly is processed in an oven that melts the preform, securing it to the shield.

Figure 8. EMI Capacitor Implementation



When this assembly is used in conjunction with a fully grounded back plane, it creates a cage that encloses the 40PC and protects it from electromagnetic interference.

Pressure and Force Sensors

40PC Building Block 2nd Level Design Consideration – Note #6

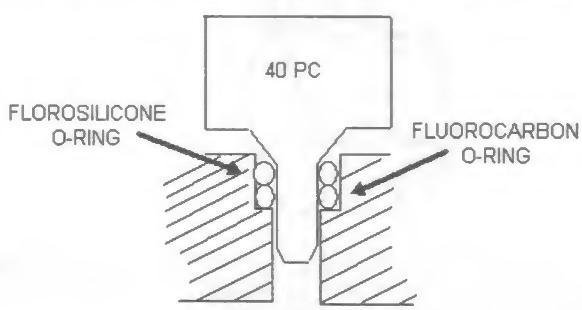
IV. MANIFOLD INTERFACE FOR THE 40PC

The sealing interface between the second level package and the 40PC must be carefully designed. Specifically, a seal material must be selected that will withstand the specified temperature extremes while also maintaining sealing capabilities when exposed to the application's pressure. In the past, finding a seal material that satisfied these requirements was extremely difficult. One approach is the use of two O-rings, each made of a different material, placed in series, where one material has exceptional sealing capabilities over the specified temperature range and the other provides resistance against the pressure media.

For example, in an automotive fuel pressure application where temperature ranges are often specified at −50° to 150°C, a fluorosilicone O-ring may be used. The fluorosilicone material provides superior sealing in this temperature range, especially at the lower temperatures, but it will not maintain its seal when exposed to automotive fuels. A fluorocarbon O-ring provides excellent resistance to automotive fuels, aliphatic hydrocarbons, and aromatic hydrocarbons, but does not possess the low temperature sealing capabilities of fluorosilicone. While each material will not meet the sealing requirements individually, assembling two O-rings, one of fluorosilicone and one of fluorocarbon, provides both temperature and pressure media sealing performance.

The O-ring materials are important to the sealing performance of the second level package. The order in which they are assembled in relation to the pressure medium is also important. The O-ring resistant to the pressure medium should be placed first in the series, closest to the medium. Referring to the automotive fuel pressure example, the placement of the fluorocarbon O-ring should be in closest proximity to the pressure medium. See Figure 9.

Figure 9. Fluorosilicone, fluorocarbon O-ring sealing



The intended sealing of the 40PC is a radial seal along the surface of the small diameter of the stainless steel port, before the taper feature of the large diameter. Using the small diameter as the sealing surface provides a large radial surface for both O-rings to seal against, and accommodates the extra room needed when the O-rings are squeezed upon assembly. The second level O-ring pocket should be designed to yield a minimum and maximum O-ring squeeze of about 16% to 30% respectively, to insure proper sealing.

Place the O-rings in the second level O-ring pocket. Then insert the 40PC port in the O-rings. Proper position of the O-rings on the port and their position in the pocket are better controlled. Care should be taken however, not to tear or rip the O-rings with the 40PC port tip during assembly. Even the slightest damage can result in an insufficient seal which could cause a failure. A polytetrafluoroethylene coating may be applied to the O-rings before assembly to create a slippery surface that will aid the insertion of the port into the O-rings.

Pressure and Force Sensors

Pressure or Force Switch Circuits – Note #7

INTRODUCTION

MICRO SWITCH solid state pressure or force sensors offer significant advantages over mechanical switches in such areas as stability, repeatability, long life, and adjustability. In addition, they provide the capability of multiple switch points.

Using MICRO SWITCH 140/160/180 and 240PC amplified pressure or force sensors as inputs (V_i), pressure switch circuits can be readily constructed. If you are using an unamplified pressure or force sensor, 120PC or FS, then you must construct a circuit from the application information on Bridge Amplifiers found on page 109. The output from that circuit then becomes your input for (Vj).

Figure 1

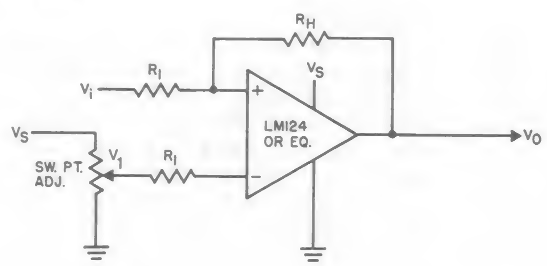


Figure 2

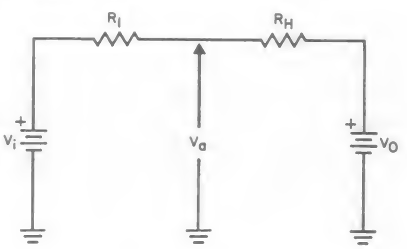
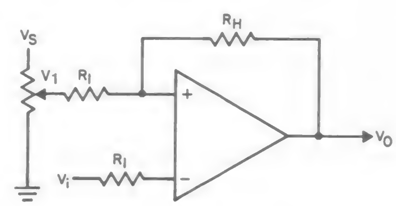


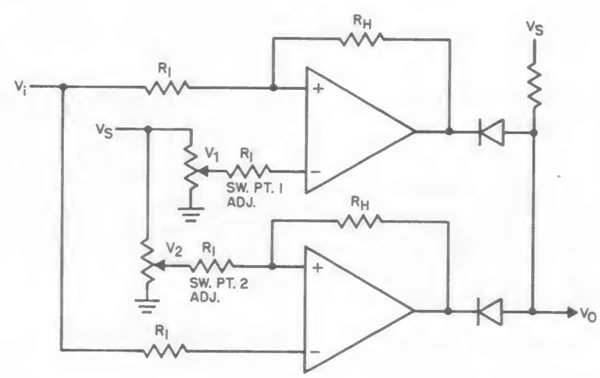
Figure 3



Configuration Of The Basic Force or Pressure Switch

An op amp with positive feedback to provide hysteresis **(Figure 2)** is the basic element of the switch. Its output (V_o) switches from zero volts to the high state (V_s – 1.5V) for $V_i \geq V_{pot}$ wiper.

Figure 4



In this circuit, R_I should be chosen to minimize loading of both the sensor output, and the potentiometer used to adjust the switch point. If a 2K pot is used, R_I = 20k is suitable. R_H is selected to provide enough hysteresis to eliminate noise-induced jitter at the switch point. The amount of hysteresis can be calculated using the equivalent circuit in **Figure 2.**

When the output (V_o) is in the low state ($V_o \cong 0$),

$$V_a(L) = \frac{V_i R_H}{R_H + R_I} \cong V_1 \text{ for } R_H >> R_I$$

When the output (V_o) is in the high state.

$$V_{a(H)} = V_{a(L)} + \frac{V_o R_I}{R_I + R_H} \cong V_{a(L)} + \frac{V_o R_I}{R_H} \text{ for } R_H >> R_I$$

The hysteresis is given by $\Delta V_a = V_{a(H)} - V_{a(L)} \cong \frac{V_o R_I}{R_H}$

If the LM124 op amp is operated from a 10V supply, V_o = 8.5V, and R_H = 5 megohms yields a hysteresis of 34 mV.

Other Configurations

1. Output switches from high to low state for: $V_i \geq V$ pot wiper **(Figure 3).**

2. Output switches from low to high for switch point $1 \leq V_i \leq$ switch point 2 (window detector) **(Figure 4).**

Pressure Sensors

Protecting Pressure Sensor Diaphragm From Rupture Due To Water Hammer – Note #8

Introduction

Many hydraulic systems exhibit short duration pressure pulses or shocks, called "water hammer." These shocks are generated by the rapid change of system flow rates by components such as compressors, pumps, pistons and valves. Water hammer can reach pressure levels far exceeding the over pressure rating of our pressure sensors causing destruction of the pressure sensing diaphragm.

There are four factors that determine water hammer:

1. System length (the longer the line, the greater the shock).
2. System pipe diameter.
3. System fluid velocity.
4. Closing time of valves or other flow modifiers.

The pressure increase in a fluid system due to water hammer can be described by:

$\Delta P = ec\Delta V$

Where:

e = density of fluid

c = velocity of sound in the system fluid (ft./sec.)

ΔV = change in velocity (ft./sec.)

ΔP = change in pressure (lb./ft.^{2})
(Divide by 144 for pressure in psi)

The magnitude of water hammer shock can be reduced thru reducing the system fluid velocity. Often the GPM (gallons per minute) flow rate can be reduced or the system pipe diameter increased.

Water Hammer Protection Systems

Fluid systems can be developed in three ways to eliminate or control water hammer.

1. Surge tank

An air chamber or surge tank can be placed between the components that generate the flow rate change, and the pressure sensor. The higher the volume of the tank, the higher the pressure shock it will absorb. Inlet and outlet ports should never be opposite each other to prevent direct transmittal of shock pulses. Some fluid collection can be expected in most pneumatic systems. The area required for the surge tank is the major problem with this approach.

2. Slowing operation

Water hammer is developed only by a rapid change in flow rate. If the operation of valves or other flow rate modifiers is slowed beyond the critical time of change (t_c), shock pulses can be prevented. Critical time of change is defined as:

$t_c = 2\ D/c$

Where:

$\mathbf{t_c}$ = Time of change (seconds).

D = Distance from flow restriction point to pressure sensor to be protected (feet).

c = Velocity of sound in system fluid (feet/second).

For most fluids, the velocity of sound lies between 1000 and 7000 feet per second. If system distances are great (a few hundred feet), the time of change can be 0.5 second or more. One problem with this approach is that some components may not accommodate such slow operation.

3. Pressure snubber

A pressure snubber is a device for slowing the rate of change of system flow. Installation of a properly sized snubber at or near the input of a pressure sensor will protect it from water hammer damage.

Typically, pressure snubbers are cylindrical cross-section devices ranging from 0.75 to 1.5 inches in diameter and 0.75 to 5.0 inches long. Two types commonly used employ either a porous metal plug or filter in the pressure path, or a movable plunger restricting the flow rate. Sensor response to significant pressure changes will be slowed from about 1.0 millisecond to as much as a few seconds when a snubber is used.

If the pressure sensor is mounted only by the input port at the end of a long pressure snubber, resistance to shock and vibration will be reduced. Rated shock and vibration divided by the increased mounting length in inches approximates the expected shock and vibration resistance. Adding a 3 inch long snubber will reduce shock and vibration resistance to about one third of the rated value.

Following is a list of vendors for pressure snubbers:

Allied Witan Company
Arcco Instrument Company, Inc.
Autoclave Engineers Inc.
Cajon Company
Chemiquip
Cutler Controls Incorporated
Duro Instrument Corporation
Enerpack Division Applied Power Inc.
Fluid Kinetics Corporation
Greer Hydraulics
ITT Grinnell Corporation
Metserco
Mid-West Instrument Division Astra Associates Inc.
Mott Metallurgical Corporation
Oligear-Ball Products
Pulsafeeder/Interpace
Sigma-Netics Incorporated
Trerice, H O Company
Weiss, Albert A & Sons Inc.

Pressure Sensors

Plumbing and Mounting Considerations – Note #9

There are many types and sizes of tubing available to fit MICRO SWITCH pressure sensors. There are several methods for connecting the tubing to the plastic pressure ports. MICRO SWITCH supplies the following information as a service to the customer. However, the user is the best judge of the proper tubing and connecting methods for each application.

Hoses/Tubing

Vinyl tubing can be used in room temperature, lower pressure (< 50 psig) applications. Vinyl is less expensive and should be used with hose clamps.

Silicon tubing is very flexible and resists temperature extremes. It should be used in lower pressure (<50 psig) applications. Hose clamps are recommended.

Tygon tubing is very flexible and is recommended for applications at room temperature and pressures below 50 psig. Hose clamps are recommended.

Urethane tubing, the most expensive, is not as flexible, but can withstand higher temperatures and pressures. Hose clamps are recommended, but may not be required.

Hose Clamps

Tyton Corporation supplies two types of hose clamps called "SNAPPER." The natural acetyl type is recommended for most applications not exceeding 200°F air temperature or 180°F water temperature. The heat stabilized glass fiber compound type is good for 400°F continuously. Snappers are also stable in a wide variety of chemicals including salts, bases, alcohols, ethers, detergents, gasoline, lubricating oils and greases. Assorted clamp sizes are available.

Pipe clamps purchased locally in the plumbing department of hardware stores and cable ties from electrical distributors may also be used to attach the tubing to the plastic ports.

Mazzer Industries supplies Mazzer-Loc JG speed fittings that work well with the 20PC Series large flow-through sensors.

Accessories

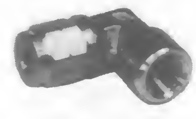
Add-on Ports

Imperial Eastman supplies many types and sizes of brass add-on ports for connecting to copper tubing.

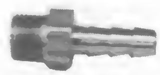
Mounting Hardware

ITW FasTex supplies a wide variety of mounting connectors, nylon screws, rivets and push pins which can be used with the pressure sensor mounting brackets.

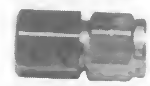
69-FL-03X02



70-FL-03X02



KF03-02PS



66-FL-03X02

68-FL-03X02

ADD-ON PORTS

HOSE CLAMPS

Table 2

Add-on Ports

68-FL-03X02	3/16″ O.D. tube to 1/8″ male pipe - male connector
69-FL-03X02	3/16″ O.D. tube to 1.8″ male pipe - male elbow
70-FL-03X02	3/16″ O.D. tube to 1/8″ female pipe - female elbow
KF03-02PS	3/16″ I.D. hose to 1/8″ male pipe - barbed port
KF04-02PS	1/4″ I.D. hose to 1/8″ male pipe - barbed port
66-FL-03X02	3/16″ O.D. tube to 1/8″ female pipe - female connector (Female connector is used in conjunction with barbed port)

Hoses/Tubing

Norton Performance Plastics Corporation
P.O. Box 3660
Akron, OH 44309-3660 USA
(330) 798-9240

United States Plastics Corporation
1390 Neubrecht Road
Lima, Ohio 45801 USA
(419) 228-2242

Clippard Instrument Laboratory, Inc.
7390 Colerain Road
Cincinnati, Ohio 45239 USA
(513) 521-4261

Hose Clamps/Accessories

Tyton Corporation
7930 North Faulkner Road
P.O. Box 23055
Milwaukee, WI 53223 USA
(414) 355-1130

Imperial Eastman Acquisition Corporation
1151 Bryn Mawr
Itasca, IL 60143 USA
(630) 285-6100

Clippard Instrument Laboratory, Inc.
7390 Colerain Road
Cincinnati, Ohio 45239 USA
(513) 521-4261

Mazzer Industries, Inc.
125 Elmgrove Park
Rochester, NY 14624
(716) 247-0311

ITW Fastex
195 Algonquin Road
Des Plaines, IL 60016-6197 USA
(847) 299-2222

Pressure Sensors

Pressure Sensor Auto-Referencing – Note #10

INTRODUCTION

Pressure sensors are not "ideal" devices. Laser trimming on MICRO SWITCH high level amplified sensors reduces null and full scale errors to approximately 1% to 2% of span, but does not completely eliminate them. Additional corrective circuitry is sometimes necessary for applications with extremely tight tolerances. Figure 1 illustrates the "ideal" pressure sensor. Output drift with time, trimming tolerances, and changes in ambient temperature all contribute to a constant offset error (common-mode error), designated by ΔV_o. Changes in ambient temperature also add another deviation, known as sensitivity shift, which changes the slope of the pressure versus voltage curve.

A family of techniques known as auto-referencing provides a powerful tool to compensate for these errors. System design engineers find the method attractive since implementation costs are minor in comparison with ultra-stable pressure sensors. Also, device accuracy is substantially increased. Either analog or digital auto-referencing is possible. This application note covers the digital method, as it is the most cost-effective and easiest to use.

COMMON-MODE AUTO REFERENCING

Common-mode errors are those present at some reference pressure and contribute the constant offset voltage in Figure 1. These errors are generally larger than the sensitivity shift, especially at pressures close to the reference pressure. Therefore, they allow the greatest accuracy improvement when auto-referenced.

Common-mode errors are easily corrected. Sample the output voltage at reference pressure and compare it to the desired reference voltage. Generate an error correction voltage and subtract it from the output signal at any "measure" pressure. See Figure 2.

Common-mode auto-referencing is expressed by the formula:

$$V_{corr} = V_{out} - \Delta V_o$$

V_{out} is any measured output signal, ΔV_o is the common-mode error, and V_{corr} is the corrected output signal. Note that no slope correction is provided for sensitivity shift error, and the actual output signal will appear as shown in Figure 3.

The basic functions required to implement common-mode auto-referencing are shown in the block diagram of Figure 4. They include analog switches, a sample-and-hold, summers, and synchronizing logic for switching between the read and reference cycles on the input and output sides of the pressure sensor.

To maintain optimum system accuracy, auto-referencing should be used as often as possible in order to eliminate errors due to power supply fluctuations and output drift with time. To assure that the pressure measurements will be the most accurate, they should immediately follow the auto-reference command.

Certain types of measurement cycles are inherently suited to auto-zeroing (reference pressure is actually zero). Ideally, there is a series of short cycles which can have a quick referencing inserted prior to each cycle. A short measurement cycle preceded by a reference point, followed by a lengthy period of no activity, is also well suited. Many applications are in one of these categories. Many that are not can be converted to the short repeated cycle format, with a little design creativity.

Figure 1. Sensor Errors

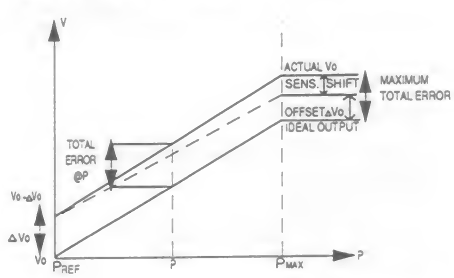
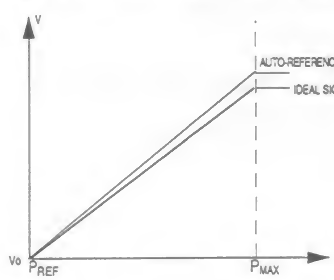


Figure 3. Auto-Referenced Signal



Examples of "ideal" applications are: weighing scale; toilet tanks; washing machines; and pressure reservoirs such as tire pressure, oil pressure, and LP gas tank pressure. The reference condition is applied before the measurement. Other categories are flow measurement and control applications, such as electronic fuel injection systems, sphygmomanometers, and forced air heating systems. Flow rate is zero at some point, usually at system power-up.

Although common-mode auto-referencing is almost a universal technique, there are situations where it would be of little value; systems with short measurement cycles where the reference point is read or manually adjusted before cycle start-up, or where the sensor is AC coupled and the DC response is ignored.

COMMANDING AUTO-REFERENCING

The key to an auto-reference circuit is applying the trigger signal to command the reference to take place at the appropriate time. There are three levels of sophistication.

Figure 2. Common-mode Errors

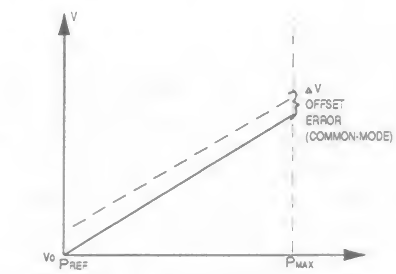
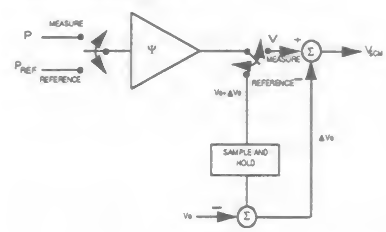


Figure 4. Basic Common-mode Auto-Referencing



Pressure Sensors

Pressure Sensor Auto-Referencing – Note #10

Manual Command

The simplest auto-referencing method is the manual command. A momentary contact switch initiates the auto-zeroing sequence. This is the most restrictive method, as it requires the user to be present while the system is running in order to periodically reference the sensor. However, it could be done as part of a routine calibration procedure.

Semi-automatic Command

The user initiates the action. After it is triggered, the system sequences through multiple functions controlled by timers or shift registers. This could include solenoid actuation to switch from measurement to reference pressure, followed by the auto-reference function, then a return to the measurement mode. Figure 4 illustrates a basic semi-automatic circuit.

Automatic Command

The system steps through multiple functions similar to the semi-automatic command. However, on returning to the measurement mode, additional timing circuitry triggers and after a set measurement time the sequence is restarted. Depending upon the degree of complexity desired, a small microprocessor-based system and its related software could consolidate the auto-reference circuitry, timing and control logic all into one unit.

ESTABLISHING A SYSTEM REFERENCE POINT

Batch processing and continuous processing are the two main categories of measurement cycle. In a batch process, a reference condition exists at some time, usually at system power-up. For example, a toilet tank has a high water level prior to flushing, corresponding to some reference pressure. When the flushing cycle is complete, the tank is filled to the previous level. The obvious point for auto-referencing is just prior to flushing when the water is at a known level. In a continuous process, there is no easily accessed reference condition. For example, the volume of fluid in a water tower is being monitored. This is a function of the depth of the water and can be sensed with a pressure sensor. Unlike the toilet, without actually taking a pressure measurement, there is no point in time at which the depth will be known.

The sensor/auto-reference/enable system can be used for a simple case when a known reference exists periodically. Also, a reference condition actuator such as a solenoid valve can be used. It can switch the sensor input from the measured pressure to some other reference pressure. The solenoid can be activated by the user, some condition such as power-up, or a timer activated circuit (see Figure 5). The valve must be activated long enough for the pressure to have a chance to stabilize so a valid reading may be taken. For instance, consider the water tower. A gage pressure sensor near the bottom senses the water depth. A vent tube to the surface serves as a pressure reference. A 3-way solenoid valve is the actuator, connecting the water and the vent to the sensor input port. A timer circuit is the enabler (see Figure 6).

Next, suppose the water exits through a single pipe of constant diameter. The velocity can be measured with a differential pressure sensor. A 2-way solenoid connected between the two inlet ports serves as the reference actuator as shown in Figure 7.

CIRCUIT EXAMPLE

The simplest auto-reference case is where the enable command is given manually and the reference condition occurs naturally. Figure 7 is the block diagram, and Figure 8 shows the actual circuit. An 8-bit A/D converter performs the sample-and-hold function, and there are several op-amp summer configurations. No actuator, such as a solenoid valve, is necessary because the reference condition occurs naturally, and the user knows when it occurs. The manual enable is a simple pushbutton momentary contact switch.

This auto-zero circuit is designed for use with a high level sensor with a null output of 1V, such as MICRO SWITCH amplified pressure sensor products. The null specification is 1V±50mV. To guarantee the ability to auto-zero under virtually all conditions, the null range used in this design is 1V±100mV.

The sensor is at null output, the only time auto-zeroing is allowed. Null output (V_{null}) ranges from 0.9 to 1.1V. At these levels, auto-zeroing requires voltage to be added in some cases and subtracted in others. To circumvent this, op-amp #1 is used as a level shifter and summer.

Figure 5. Auto-Reference with Reference Condition Actuators

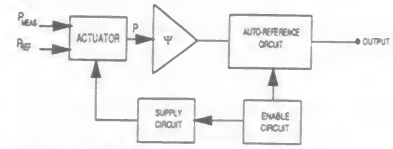


Figure 6. Timer Actuated Circuit, Single Port Sensor

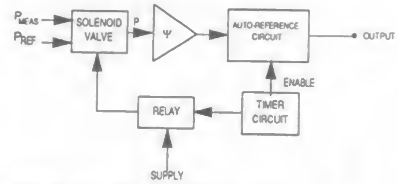
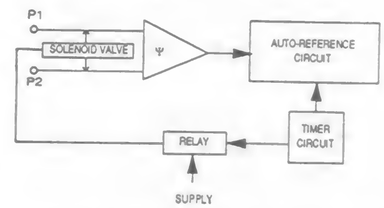


Figure 7. Timer Activated Circuit, Dual Port Sensor



100mV is added to the sensor output to shift the null range to 1.0 - 1.2V. Now, voltage need only be subtracted to provide auto-zeroing. The summer portion of op-amp #1 subtracts the auto-zero correction voltage (V_{corr}) from this shifted null range and the auto-zeroed signal appears at V_{out}.

The output of op-amp #2 is $V_{out} + V_{corr}$. Since $V_{out} = V_{null} + 100mV - V_{corr}$, a simple substitution shows that the output is actually the shifted sensor null output, V_{null} + 100mV. Consequently, the input to the V_{in} pin on the A/D converter varies from 1 to 1.2V. The conversion range is properly scaled to 1 - 1.2V, to provide maximum possible resolution. With this scaling, a 1V input corresponds to a digital output of all zeros, and a 1.2V input provides all ones at the output. Each output bit is connected to a voltage follower to prevent exceeding the current drive capabilities of the A/D converter, which would pull down the voltage at the outputs. Each of the 8 bits is connected in an inverting summing amplifier configuration using op-amp #3. The negative feedback resistor has been selected such that the maximum digital output (all bits logic "1") provides an analog voltage of

−200mV, and the minimum digital output (all bits logic "0") provides an analog voltage of 0mV. This voltage is fed into op-amp #4 (a unity gain inverting amplifier), whose output is the offset correction voltage V_{corr}. It ranges from 0mV to 200mV when the shifted null output is 1V to 1.2V. V_{corr} is then subtracted from the shifted null output, resulting in the auto-zeroed value of 1.0V at V_{out}.

The A/D converter ADC0801 allows a great deal of flexibility in setting the dynamic voltage range of the analog input voltage. $V_{in}^{(+)}$ varies from 1 to 1.2V. The 200mV span is set by applying a 100mV signal at $V_{ref}/2$. The 100mV signal is a temperature-stable voltage reference consisting of an LM336 voltage-reference and an LM124 op-amp circuit. The 1V offset is absorbed by applying a 1V signal to the $V_{in}^{(-)}$ differential input pin, which can be made temperature stable in a similar fashion if so desired.

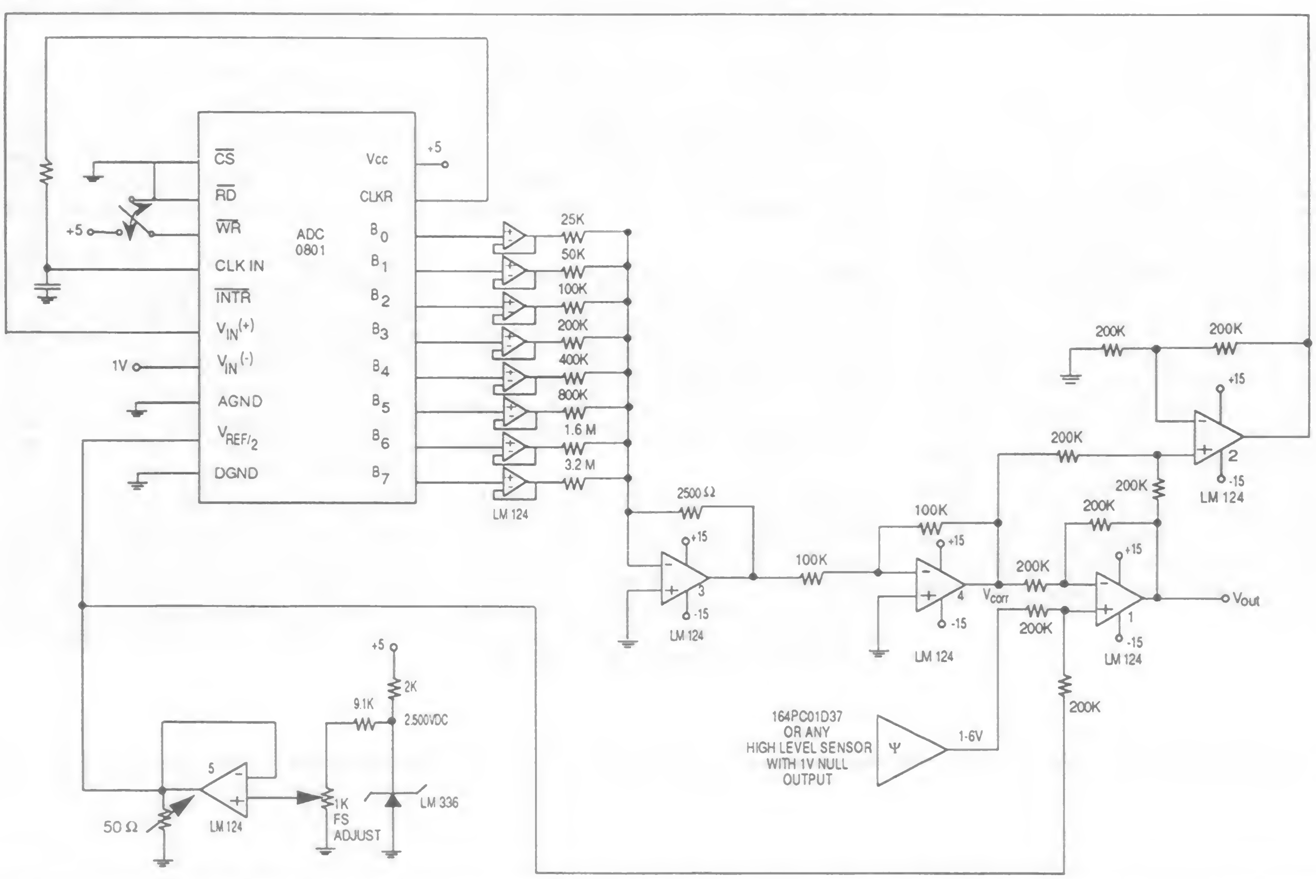
Commanding auto-zeroing is relatively simple. The WR pin on the ADC0801 should normally be at a high level. A pushbutton switch brings it to a low level, conversion begins and auto-zeroing occurs. When it is brought back to a high level, the digital outputs latch and remain at that level until auto-zeroing is again commanded.

This circuit is designed to auto-zero a signal of 1V = 100mV. Adjusting this range to suit your needs is simple. First, set the reference voltage at the output of op-amp #5 by adjusting the 50 ohm potentiometer value to set the span for the A/D converter. This provides the appropriate level shifting for the sensor null. Next, change the feedback resistor connected to op-amp #3 to provide the new correction voltage span. Then, if null offset is not 1V, change the $V_{in}^{(-)}$ input to the new offset value. When the auto-zero range is changed, keep in mind that there is a trade-off. As the span increases, resolution of the correction decreases. The designer determines the allowable resolution for a given auto-zero application. If a greater resolution is necessary, either decrease the auto-zero range or switch to a larger bit A/D converter. Each additional bit will increase resolution by a factor of two.

ACCURACY

Auto-referencing replaces common-mode error sources. The accuracy limits of the auto-reference circuit replace them. Accuracy is related to the resolution of the A/D converter and the reference drift over temperature is now only a function of the stability of the reference voltage applied to the A/D converter. With an 8-bit converter, the common-mode error can be reduced by as much as 250 times, leaving only the sensitivity shift (normal-mode) error. This is a significant improvement for the added cost involved. In any application where maximizing sensor accuracy is of value, consider an auto-referencing circuit.

Figure 8. Auto-Zero Circuit



Pressure Sensors

Conversion Factors

CONVERSION FACTORS

Converting To PSI

1 in. H_2O (@ 0°C) = 3.6127 × 10^{-2} psi
1 in. H_2O (@ 20°C) = 3.6063 × 10^{-2} psi
1mm H_2O (@ 0°C) = 1.4223 × 10^{-3} psi
1mm H_2O (@ 20°C) = 1.4198 × 10^{-3} psi
1 in. Hg (@ 0°C) = .49118 psi
1mm Hg (@ 0°C) = 1 TORR = 1.9337 × 10^{-2} psi
1 bar = 14.504 psi
1mbar = 1.4504 × 10^{-2} psi
1 Pa = 1.4504 × 10^{-4} psi
1 kPa = .14504 psi
ATM = 14.696 psi

Example:
Convert 3.0 ATM to psi:

$$3.0 \text{ ATM} \times \frac{14.696 \text{ psi}}{\text{ATM}} = 44.088 \text{ psi}$$

Converting From PSI

1 psi = 27.68 in. H_2O (@ 0°C)
1 psi = 27.73 in. H_2O (@ 20°C)
1 psi = 703.05mm H_2O (@ 0°C)
1 psi = 704.33mm H_2O (@ 25°C)
1 psi = 2.0359 in. Hg (@ 0°C)
1 psi = 51.714mm Hg = 51.714 TORR (@ 0°C)
1 psi = 6.8946 × 10^{-2} bar
1 psi = 68.946 mbar
1 psi = 6.8946 × 10^{3} Pa
1 psi = 6.8946 kPa
1 psi = 6.8045 × 10^{-2} ATM

Example:
Convert 6.0 psi to mbar:

$$6.0 \text{ psi} \times \frac{68.946 \text{ mbar}}{\text{psi}} = 413.676 \text{ mbar}$$

Temperature

$$°C = \frac{(°F - 32)}{1.8}$$

$$°F = (1.8 \times °C) + 32$$

Metric

mm = 0.03937 in.	in. = 25.4 mm
cm = 0.3937 in.	in. = 2.54 cm
m = 39.37 in.	in. = 2.54 × 10^{-2}m

Key:
psi = lbs. per square inch
in. H_2O = inches of water
in. Hg = inches of mercury
mm Hg = millimeters of mercury
bar = bar
mbar = millibar
kPa = kilopascal = 1000 (N/m^2)
ATM = atmosphere
Pa = pascal

ALTITUDE (Feet)	EQUIVALENT PRESSURE (Inches of Mercury)
−1,000	31.0185
−900	30.9073
0	29.9213
500	29.3846
1,000	28.8557
1,500	28.3345
2,000	27.8210
3,000	26.8167
4,000	25.8418
6,000	23.9782
8,000	22.2250
10,000	20.5770
12,000	19.0294
14,000	17.5774
16,000	16.2164
18,000	14.9421
20,000	13.7501
22,000	12.6363
25,000	11.1035
30,000	8.88544
35,000	7.04062
40,000	5.53802
45,000	4.35488
50,000	3.42466

Airspeed	
Knots	Inches of Mercury
60	0.1727
80	0.3075
100	0.4814
110	0.5832
120	0.6950
130	0.8168
140	0.9488
150	1.0910
175	1.4918
200	1.9589
225	2.4943
250	3.1002
275	3.7792
300	4.5343
325	5.3687
350	6.2859
375	7.2900
400	8.3850
425	9.5758
450	10.8675
475	12.2654
500	13.7756
525	15.4045
550	17.1590
575	19.0465
600	21.0749
650	25.5893
700	30.7642
750	36.5662
800	42.9378
850	49.8423
900	57.2554
1,000	73.5454

1 knot ≅ 1.15 statute miles

Microbridge Airflow Sensors

Particle Contamination and Filter Manufacturers

NOTICE

Dust particle contamination may be present in some applications. Appropriate measures should be taken to minimize the effect of particulate contamination.

The sensor design directs dust particles in the air stream flow past the sense element parallel to its surface. In addition, the microstructure IC produces a thermophoretic effect, which repels micrometer-sized dust particles away from the microbridge structure.

Dust adherence to chip edges and channel surfaces can be prevented using a simple filter. A disposable five-micron filter used in series on the upstream side of the airflow devide will provide adequate filtering in most applications.

CAUTION

PRODUCT DAMAGE

AWM Microbridge Mass Airflow Sensors are **NOT** designed to sense liquid flow and will be damaged by liquid flow through the sensor.

U.S. Suppliers

Pall Corporation
2200 Northern Blvd.
East Hills, NY 11548-1289
Tel: (516) 484-5400
1-800-645-6532 (USA Only)
Fax: (516) 484-6164
Internet: www.pall.com

Pall - DFFH200

These filters exhibit little lot-to-lot variation. Pressure drop at 1000 sccm mass flow is less than 0.010″ H_2O. They are relatively expensive and larger in size.

Pall Gelman Sciences
600 South Wagner Road
Ann Arbor, MI 48103-9019
Tel: (734) 665-0651
1-800-521-1520 (USA Only)
Fax: (734) 913-66114
Internet: www.pal.com/gelman

Gelman Acrodisc - 4199

These filters exhibit roughly 25% lot-to-lot variation. Differential pressure drop is approximately 0.130″ to 0.160″ H_2O at 100 sccm and 0.600″ to 0.900″ H_2O at 500 sccm mass flow. These filters are considered medically sterile and are relatively small in size.

Gelman Acro - 50 4258

These filters are highly efficient and exhibit little lot-to-lot variation. Typical pressure drop across the filter is 0.030″ H_2O at 100 sccm mass flow. They are larger in size, medium priced and considered medically sterile.

Parker Hannifin Corp. - Filtration Group
Finite Filter Company
500 Glaspie Street
Oxford, MI 48371
Tel: (810) 628-6400
Fax: (810) 628-1850
Internet: www.parker.com

Finite Filter - IDN-14G

Finite filters exhibit minor lot-to-lot variation. Differential pressure drop is less than 0.020″ H_2O at 100 sccm mass flow and less than 0.060″ H_2O at 500 sccm mass flow. These filters are smaller in size and made of transparent plastic for ease of inspection.

International Suppliers

AUSTRALIA
Pall Gelman Sciences
P.O. Box 4100
Lane Cove DC, Sydney
NSW 2066
Tel: (61-29) 428-2333
Fax: (61-29) 428-5610

FRANCE
Pall Gelman Sciences
Cite Descartes - 10 allee
Lorentz
77420 Champs sur Marne
Tel: (33-1) 6461-5252
Fax: (33-1) 6461-5262

GERMANY
Pall Gelman Sciences
Arheilger Weg 6
D-64380 Roβdorf
Tel: (49-6) 154-60220
Fax: (49-6) 154-602260

JAPAN
Pall Gelman Sciences
1-9-12 Kita-Ueno
Taito-ku, Tokyo 110
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Fax: (81-3) 3844-5433

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Gelman Sciences, Ltd.
Brackmills Business Park
Caswell Road
Northampton NN4 7EZ
Tel: (441-604) 70-4704
Fax: (441-604) 70-4724

BRAZIL
Parker Hannifin Industria
e Comercio Ltda.
Irlemp Filter Division
Via Anhanguera, KM, 25,5 - Trevo Perus
05276-000 Sao Paulo, SP, Brazil
Tel: (55) (11) 847-1222
Fax: (55) (11) 847-1610

FINLAND
Parker Hannifin Corporation
Finn Filter Division
Fin-31700
Urjala AS., Finland
Tel: (358) 37-54100
Fax: (358) 37-5410 100

UNITED KINGDOM
Parker Hannifin Corporation
Filter Division Morley
Peel Street
Morley, Leeds
LS27 8EL England
Tel: (44) 113 253-7921
Fax: (44) 113 252-7815

Microbridge Airflow Sensors

Measuring Low Differential Pressures
Altitude and Gas Density Correction – Note #1

Microbridge mass airflow sensors measure actual mass flow of a gas media (assuming thermal conductivity of the gas is held constant). The actual flow of the gas media is driven by a pressure gradient flowing from a higher pressure region to a lower pressure region. The pressure differential required to drive flow through the microbridge mass flow sensor is considered very low, typically less than two inches water column (less than five mBar) full scale.

As a result, microbridge mass flow sensors are commonly used to measure differential pressures as low as 0.001″ H_2O (0.002 mBar). In these applications, the microbridge sensors actually sense mass gas flow. However, the product is specified and calibrated against differential pressure. To measure differential pressure, the application must be able to provide gas flow through the sensor (gas density remaining constant).

This can be referenced to the Ideal Gas Law which states: $PV = nRT$. This implies that while measuring differential pressures, the sensor gain will be directly proportional to the absolute pressure (absolute density) of the gas. Microbridge mass flow sensors are calibrated at 850 feet (260 meters) above sea level with the absolute pressure at approximately 740 torr.

At sea level with absolute pressure at 760 torr, the sensor voltage output will be higher by an approximate factor of:

$$1 + \frac{(760\text{-}740)}{740} \text{ or } 1.027$$

Additionally, if located in Salt Lake City - Utah, where the altitude is 4,200 feet (1,270 meters) above sea level, the standard absolute pressure is 650 torr.

This will result in the sensor voltage output being reduced by an approximate factor of:

$$\frac{1 + (650\text{-}740)}{740} \text{ or } 0.8784$$

See Table 1 below for additional approximations for various altitude corrections.

When using microbridge mass flow sensors to measure low differential pressures, the temperature of the gas can also affect the relative gas density. Density changes due to temperature can cause a shift in the sensor output gain. The shift will be proportional to the change in the absolute gas density (referenced to 23°C).

NOTE: When measuring actual mass flow, the microbridge sensor is insensitive to altitude and gas density changes.

Table 2- Approximate Altitude Correction Factors

Altitude	Absolute Pressure Torr	mBar	kPa	Approximate Correction Factors	Representative Cities
0 m (0 ft.)	760	1000	100	1 + (760-740)/740 = 1.027	London (U.K.), New York, NY (US), Tokyo (Japan)
250 m (820 ft.)	740	984	98	1 + (740-740)/740 = 1.000	Minneapolis, MN (US), New Delhi (India), Turin (Italy)
500 m (1,650 ft.)	720	958	96	1 + (720-740)/740 = 0.973	Munich (Germany), Santiago (Chile), Spokane, WA (US)
750 m (2,500 ft.)	694	925	92	1 + (694-740)/740 = 0.938	Ankara (Turkey), Tucson, AZ (US)
1,500 m (5,000 ft.)	632	842	84	1 + (632-740)/740 = 0.854	Denver, CO (US), Johannesburg (S. Africa)
2,250 m (7,500 ft.)	575	766	77	1 + (575-740)/740 = 0.777	Addis Ababa (N.E. Africa), Mexico City (Mexico)
3,000 m (10,000 ft.)	523	697	70	1 + (523-740)/740 = 0.707	La Paz (Bolivia), Leadville, CO (US)

Microbridge Airflow Sensors

High Flow Capability
Bypass Design Considerations – Note #2

Many users would like to take advantage of the cost-effective, high-performance characteristics of the microbridge mass airflow sensor. Some of these applications require the ability to measure flow ranges higher than the capability of existing microbridge sensors. Others may simply wish to take advantage of the flow range capability of the high-flow AWM5000 series, but require the small size and fast response times of the AWM2000/AWM3000 series.

One way to achieve higher flow range capability is through the use of a bypass configuration. This provides a higher main flow channel than the lower bypass (sensor) flow channel. In this configuration, only a sample of the total flow actually gets directed through the bypass channel and the sensor. The amount of flow directed through the microbridge device is determined by the "bypass ratio." The smaller the ratio, the more predictable and stable the sensor output throughout the measured flow range.

Simple bypass configurations can be easily incorporated into most applications. The bypass ratio can be calculated by determining the cross sectional area of the flow channel above the microbridge chip compared to the cross sectional area of the main flow channel at its point of greatest restriction. The cross sectional area above the microbridge chip is determined according to the internal design of the sensor flow tube (See Table 1).

Figure 1 Typical bypass design

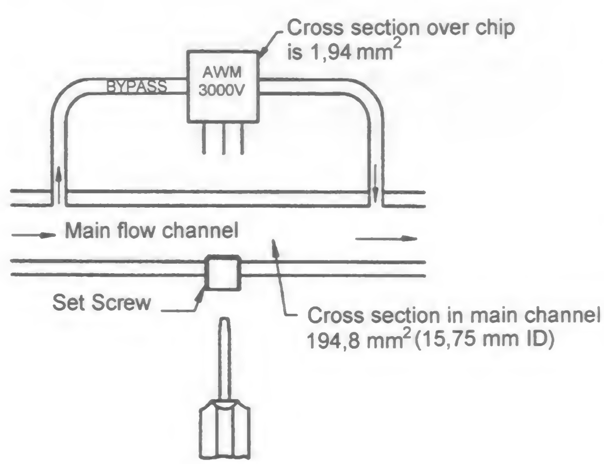


Figure 1 is a typical bypass configuration. In this design, the main flow channel has an ID of 15,75 mm which results in a cross sectional area of 194,83 mm². The cross sectional area above the microbridge chip is 1,95 mm². This yields an approximate bypass ratio of 100 to 1. This design incorporates a variable flow restriction (set screw) that can be used to calibrate a specific bypass ratio.

Applications that incorporate bypass designs with ratios of 100 to 1 or greater may experience noticeable errors near zero flow. Large bypass ratios require a larger pressure drop to adequately direct flow to the sensor. Under very low flow conditions, there may not be sufficient pressure drop to drive flow through the bypass (sensor) flow channel. There may also be considerable variation in performance due to variety of bypass channel designs and geometries. In addition, device-to-device variation may be amplified when used in conjunction with high bypass ratios.

For example, an application that needs 5 SLPM flow measurement capability could potentially use an AWM3300V (1,000 sccm flow range device). This would simply require the use of two T-connections and a bypass flow channel using 1/8 inch ID tubing. This is the same tubing size recommended for connecting the sensor. With this configuration, the bypass ratio is 4 to 1. This will allow 4 liters of flow through the bypass channel with 1 liter of flow through the sensor channel, permitting a total of 5 liters of flow through the system.

The same size tubing, 1/8 inch ID, to bypass an AWM5000 series sensor would provide a 1 to 1 bypass ratio, thus doubling the flow capability of this sensor. Further, using a 3/8 inch ID tubing to bypass the AWM5000 series would provide a 3 to 1 bypass ratio, thus quadrupling the flow range capability for the AWM5000 sensor. This 3 to 1 bypass configuration used with an AWM5104VN (20 SLPM flow range) would provide flow measurement capability up to 80 SLPM.

Table 1 Cross-sectional area above microbridge chip

Catalog Listing	Area*
AWM2100V	1.57 mm²
AWM2300V	1.94 mm²
AWM3100V	1.57 mm²
AWM3300V	1.94 mm²
AWM42150VH	1.75 mm²
AWM42300V	1.75 mm²
AWM43300V	1.75 mm²
AWM43600V	12.07 mm²
AWM5000 Series	45.60 mm²

* All values are approximate.

Microbridge Airflow Sensors

High Flow Capability
Bypass Design Considerations – Note #2

In applications where the desired flow rate exceeds the flow specifications for standard MICRO SWITCH products, a bypass flow channel (see Figure 2.) can be configured. A bypass (appropriately sized) consists of a Microbridge sensor on parallel with the main flow channel. In this configuration, only a portion of the total flow rate will pass through the bypass channel and sensor, while the majority of the total flow passes through the main flow channel. Below is an example of calculations needed to properly size the bypass configuration and help select an appropriate Microbridge Sensor.

In this example, a multi-channel bypass with a Microbridge Sensor is configured for 100 liter/min flow rate.

Step 1: Convert desired flow rate from liters/min to m^3/sec by the following formula:

Enter Desired Flow Rate = 100 liters/min

liter/min X .00001666667 = $\boxed{0.001666667}$ m^3/sec

Enter the above calculated value into INPUT area below as the Total Volumetric Flow (Q_{total}).

Step 2: Calculate Reynold's number for desired volumetric flow. It is important that desired volumetric flow is in the laminar flow range. This means that the Reynold's number must be 2000 or less. Enter desired volumetric flow in INPUT area below. Make adjustments in INPUT area to diameter (D) and quantity (N) of flow channels for a Reynold's number (Re) of 2000 or less (Laminar Flow):

$$Re = \frac{4 * \rho * Q / N}{\pi * D * \mu} = \frac{0.000347826}{1.80539E\text{-}07} = \boxed{1926.59302}$$

Step 3: Calculate approximate pressure drop across Laminar Flow Area (due to flow). Use the following equation:

$$\Delta Pflow = \frac{128 * \mu * (Q/N) * L}{\pi * D^4} = \frac{8.52851E\text{-}09}{3.19246E\text{-}10} = \begin{array}{l} 26.71 \ N/m^3 \\ \boxed{0.107} \ ''H^2O \end{array}$$

Step 4: Calculate approximate pressure loss at inlet and outlet. Use the following formula:

first, calculate velocity: $V = \dfrac{4 * Q}{\pi * N * D^4} = 9.2$ m/sec

next, use calculated velocity (V) in equation below and calculate Inlet and Outlet pressure loss:

$$\Delta P_{inlet/outlet\ loss} = \frac{(K_{inlet} + K_{outlet}) * V^2 * \rho}{2} = \begin{array}{l} 75.39 \ N/m^2 \\ \boxed{0.303} \ ''H^2O \end{array}$$

Table 1

Parameter	Definitions		Input Range	Constant @ 20°C	Metric Units
ΔP =	Delta Pressure	=	—		N/m^2
μ =	Viscosity Air	=	1.81E-05	—	$(N*s)/m^2$
ρ =	Density Air	=	1.20	—	kg/m^3
π =	PI	=	—	3.141592654	—
D =	Diameter of Single Flow Channel	=	0.003175	—	m
N =	Number of channels	=	23	—	—
L =	Length of By-Pass	=	0.0508	—	m
Q_{total} =	Total Volumetric Flow Rate	=	0.001666667	—	m^3/sec
K_{inlet} =	Inlet Loss Coefficients	=	0.5	—	—
K_{outlet} =	Outlet Loss Coefficients	=	1.0	—	—
g =	Acceleration of gravity constant	=	—	9.806	m/sec^2

Microbridge Airflow Sensors

High Flow Capability
Bypass Design Considerations – Note #2

Step 5: Calculate approximate Total Pressure drop across Laminar Flow Area. Use the following formula:

$$\Delta P_{total} = \Delta P_{inlet/outlet\ loss} + \Delta P_{flow} = 102.11\ N/m^2 = \boxed{0.41}\ ''H^2O$$

Note: ΔP_{total} is an approximate value. Testing or further analysis is needed for each specific design.

Step 6: Select appropriate Microbridge sensor that has a full scale pressure drop that is equal to or greater than calculated Total Pressure Drop (ΔP_{total}) using Table 2 below:

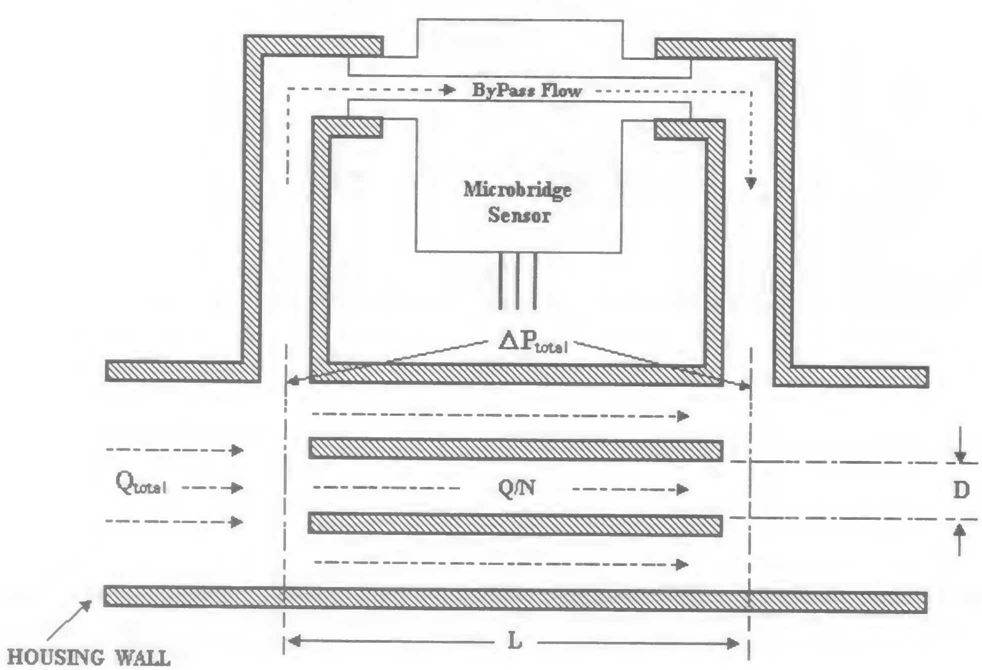
Table 2

Product	Rated Flow	Rated Pressure	Output Type	Select by Typical Full Scale Pressure Drop
AWM2100V	±200 sccm	N.A.	±44.5 mv	.20 ″H_2O or 49.8 N/m^2
AWM2150V	±30 sccm	N.A.	±14 mv	.20 ″H_2O or 49.8 N/m^2
AWM2200V	N.A.	0-2 ″H_2O	±31.75 mv	2.0 ″H_2O or 498 N/m^2
AWM2300V	0-1000 sccm	N.A.	±55.5 mv	1.3 ″H_2O or 324 N/m^2
AWM3100V	0-200 sccm	N.A.	1-5 Vdc	.20 ″H_2O or 49.8 N/m^2
AWM3150V	0-30 sccm	N.A.	1-5 Vdc	.20 ″H_2O or 49.8 N/m^2
AWM3200CR	N.A.	0-2 ″H_2O	4-20 mA	2.0 ″H_2O or 498 N/m^2
AWM3201CR	N.A.	0-0.5 ″H_2O	4-20 mA	.50 ″H_2O or 125 N/m^2
AWM3200V	N.A.	0-2 ″H_2O	1-5 Vdc	2.0 ″H_2O or 498 N/m^2
AWM3300V	0-1000 sccm	N.A.	1-5 Vdc	1.3 ″H_2O or 324 N/m^2
AWM42150VH	±25 sccm	N.A.	±8.5 mv	.20 ″H_2O or 49.8 N/m^2
AWM42300V	0-1000 sccm	N.A.	±55.5 mv	.90 ″H_2O or 224 N/m^2
AWM43300V	0-1000 sccm	N.A.	1-5 Vdc	.90 ″H_2O or 224 N/m^3
AWM43600V	0-6 slm	N.A.	1-5 Vdc	8 ″H_2O or 1992 N/m^4

In this case, using the By-Pass Configurations for flows up to 100 LPM with a ΔP = 0.37 ″H_2O, the following listings would work: AWM2200V, AWM2300V, AWM3200V, AWM3300V, AWM3200CR, AWM42300V, and AWM43600V depending on desired outputs and flow ranges.

Figure 2

BY-PASS CONFIGURATION DRAWING



Microbridge Airflow Sensors

Gas Correction Factors – Note #3

Microbridge mass airflow sensors operate by measuring the rate of relative heat transfer from a heater resistor to a temperature sensing resistor located on either side of the heater. The heat transfer is proportional to the mass flow. Offsets in the sensor sensitivity (thermal efficiency) will occur if the thermal properties of the medium change. The dominate factor is the thermal conductivity of the gas being measured. Additionally, heat capacity and gas viscosity cause lesser effects.

Heat capacity and gas viscosity are constants for a given gas. However, if the gas composition changes, these properties may also change. Fortunately, air, nitrogen, and oxygen have nearly identical properties.

The 0.5% Argon (Ar) in air is not significant, nor is the relative humidity from 0 to 99% at temperatures less than 40°C (104°F). Humidity levels of 100%, with temperatures greater than 40°C (104°F), indicate that more than 1% of the atmosphere is water. This may cause a measurable increase in sensor output. The actual offsets from Argon and 100% humidity are in opposite directions and may partially cancel each other at temperatures less than 40°C (104°F).

Approximate Gas Correction Factors

Gas Type	Approximate Correction Factor
Helium (He)	0.5*
Hydrogen (H_2)	0.7*
Argon (Ar)	0.95
Nitrogen (N_2)	1.0
Oxygen (O_2)	1.0
Air	1.0
Nitric oxide (NO)	1.0
Carbon monoxide (CO)	1.0
Methane (CH_4)	1.1
Ammonia (NH_3)	1.1
Nitrous oxide (N_2O)	1.35
Nitrogen dioxide (NO_2)	1.35
Carbon dioxide (CO_2)	1.35

Note: Gas correction factors are referenced to nitrogen (N_2) as calibration gas type. Approximate gas correction factors are provided as guidelines only. Individual gas types may perform differently at temperature extremes and varying flow rates.

*When sensing Hydrogen (H_2) or Helium (He) it may be necessary to power the mass flow sensors using increased supply voltage: Hydrogen, 12 VDC typical, and Helium, 15 VDC typical.

Carbon monoxide (CO) and nitric oxide (NO) have properties similar to air. Carbon dioxide (CO_2) will have increased sensitivity compared to that of air (roughly 135%, this may vary with flow rate). Gases similar to CO_2 are nitrous oxide (N_2O) and nitrogen dioxide (NO_2).

Helium has such a high thermal conductivity that it will saturate the heater control circuit on the sensor unless supply voltage is increased to 15 VDC*. Helium sensitivity is then reduced to the point where two liters of Helium will produce an output eqivalent to one liter (1,000 sccm) mass flow of air or nitrogen. The correction factor will be dependent upon temperature and actual flow rate.

Hydrogen flow measurement requires the use of a special sensor. These devices provide normal operation when sensing hydrogen flow and are designated with an "H" at the end of the catalog listing. Established hydrogen stable listings include AWM2100VH, AWM2300VH and AWM42150VH.

Microbridge Airflow Sensors

Gas Media Compatibility – Note #4

The microbridge mass airflow sensor incorporates a limited number of wetted materials in the construction of the device. The wetted materials in the sensor are fairly non-reactive and are compatible with a wide variety of gaseous media. Table 1 and Table 2 list wetted sensor materials and associated media compatibility.

NOTICE
Filtering is highly recommended for use in applications that may contain dust particle contamination that can degrade sensor performance over time. See Particle Contamination and Filter Manufacturers, page 126, for more information.

CAUTION
PRODUCT DAMAGE
AWM Series microbridge mass airflow sensors are **NOT** designed to sense liquid flow and will be damaged by liquid flow through the sensor.

MICROBRIDGE—WETTED SENSOR MATERIALS

Sensor material	AWM1000	AWM2000	AWM3000	AWM40000	AWM5000
Silicon	X	X	X	X	X
Silicon nitride	X	X	X	X	X
Gold	X	X	X	X	X
Aluminum oxide	X	X	X	X	X
Epoxy sealant	X	X	X	X	X
Fluorocarbon				X	X
Polyester					X
Polyetherimide	X	X	X	6 SLPM Only	
316 Stainless steel	AWM1200V	AWM2200V	AWM3200V		

MICROBRIDGE—GAS MEDIA COMPATIBILITY

Gas Media	AWM1000	AWM2000	AWM3000	AWM40000	AWM5000
Air	X	X	X	X	X
Nitrogen	X	X	X	X	X
Oxygen	X	X	X	X	X
Argon	X	X	X	X	X
Helium	15 VDC Supply	15 VDC Supply	15 VDC Supply	15 VDC Supply	15 VDC Supply
Hydrogen*	Special listing	Special listing	Special listing	Special listing	Special listing
Natural Gas	X	X	X	X	X
Nitrous oxide	X	X	X	X	X
Anesthetic Gasses	N/A	N/A	N/A	N/A (Except 6 SLPM)	X
Carbon dioxide	X	X	X	X	X
Nitric oxide	Dry Gas Only	Dry Gas Only	Dry Gas Only	Dry Gas Only	Dry Gas Only
Sulfur oxide	Dry Gas Only	Dry Gas Only	Dry Gas Only	Dry Gas Only	Dry Gas Only
Water vapor	Non-Condensing	Non-Condensing	Non-Condensing	Non-Condensing	Non-Condensing
Ammonia gas	Dry Gas Only, <1%	Dry Gas Only, <1%	Dry Gas Only, <1%	Dry Gas Only, <1%	Dry Gas Only, <1%
Chlorine gas	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Hydrogen sulfide	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%

***Note:** Applications involving hydrogen gas sensing require the use of a sensor identified by the letter "H" in the catalog order guide. Current hydrogen stable catalog listings are: AWM2100VH, AWM2300VH, and AWM42150VH. Other listings may be established as hydrogen stable devices. Please contact the Application Center for assistance at 1-800-537-6945.

INTRODUCTION

Linear temperature sensors have a major advantage. The output can be easily conditioned to achieve a desired voltage output span over a particular temperature range. A linear output voltage allows ease of interface to data acquisition systems and programmable controllers. By adjusting the circuit gain, the sensitivity of the output can be adjusted over the total range such as 10° to +40°C.

INTERFACING WITH 1-5V CIRCUIT

If more than 1 mA of current flows through the TD, self-heating will occur. The self-heating effect is typically 0.2°C/milliwatt. The circuits in **Figure 1** and **Figure 2** provide a maximum current flow of 1 mA.

SETTING DESIRED SPAN

The circuit gain depends on the temperature range you want to sense. The offset adjustment is, in turn, dependent on the chosen gain. The transfer function for both circuits (Figures 1 and 2) is as follows:

$$(R_5/R_4 + 1) \bullet V[R_{TD}/(R_{TD} + R_7)] - (R_5/R_4)(1 + R_3/R_2)V_1 = v_O$$

Only two elements are unknown: the offset (v_1), and the circuit gain ($R_5/R_4 + 1$). To set the desired span, two equations for the two unknowns must be created and solved. To simplify these calculations, the following assumption is made:

$$R_5/R_4 = R_2/R_3$$

The second assumption is that no self-heating of the TD element will occur: the values of V and R_7 are constant at the values indicated.

$$V[R_{TD}/(R_{TD} + R_7)] = 5[R_{TD}/(R_{TD} + 5110)]$$

These assumptions reduce the transfer function to:

$$(R_5/R_4 + 1) \bullet 5[R_{TD}/(R_{TD} + 5110)] - (R_5/R_4 + 1)v_1 = v_O$$

To create the first of the two simultaneous equations, the value of R_{TD} for the desired minimum temperature is taken from **Table 1**. (R_{TD} at 20°C equals 2000 Ohms, and v_O = 1V.) For the second equation, the value of R_{TD} for the desired maximum temperature is taken from the table, and v_O = 5 V.

The two equations are then solved for the gain ($R_5/R_4 + 1$) and the offset (v_1). The following example shows how this is accomplished.

Desired temperature range: 0° to 60°C.
Voltage output over range: 1 to 5 V.

Equation 1: R_{TD} at 0°C is 1854 Ohms.

$$(R_5/R_4 + 1) \bullet 5[1854/(1854 + 5110)] - (R_5/R_4 + 1)v_1 = 1\text{ V}$$

Equation 2: R_{TD} at 60°C is 2314 Ohms.

$$(R_5/R_4 + 1) \bullet 5[2314/(2314 + 5110)] - (R_5/R_4 + 1)v_1 = 5\text{ V}$$

Step 1: subtract equation 1 from equation 2.

$$(R_5/R_4 + 1)(1.558) - (R_5/R_4 + 1)V_1 = 5$$
$$(R_5/R_4 + 1)(1.331) - (R_5/R_4 + 1)v_1 = 1$$
$$(R_5/R_4 + 1)(.227) - 0 = 4$$
$$(R_5/R_4 + 1) = 4(1/.227)$$
$$(R_5/R_4 + 1) = 17.62 = \text{GAIN}$$

Step 2: substitute ($R_5/R_4 + 1$) = 17.62 into equation 1 and solve for V_1.

$$(17.62)(1.331) - (17.62)v_1 = 1$$
$$23.454 - 17.62v_1 = 1$$
$$22.452 = 17.62v_1$$
$$1.274 = v_1 = \text{OFFSET}$$

In order to transfer this information into the circuit in **Figure 1**, choose appropriate values for R_4 and R_5 such that:

$$(R_5/R_4 + 1) = \text{GAIN}$$

For this example, R_4 = 1 K Ohm and R_5 = 16.62 K Ohm would be appropriate.

Choose R_2 and R_3 based on $R_2/R_3 = R_5/R_4$. For this example, choose $R_2 = R_5$ = 16.62 K Ohm, and $R_3 = R_4$ = 1 K Ohm.

To set the offset v_1 using potentiometer R_1, temporarily insert an equivalent discrete resistor in place of the TD element. It should be equal to the TD resistance at the minimum desired temperature (1854 Ohms from the example). Adjust R_1 until the output voltage is 1 V. Replace the discrete resistor with the TD element. The circuit is now set and ready to give 1 V to 5 V output over the chosen temperature range.

Figure 1
5.0 V Regulated Circuit

1. LM358 is a general purpose operational amplifier.
2. 2N2222 is a general purpose NPN transistor.
3. Resistor accuracy should be within ±1%.
4. v_O is measured with respect to ground.

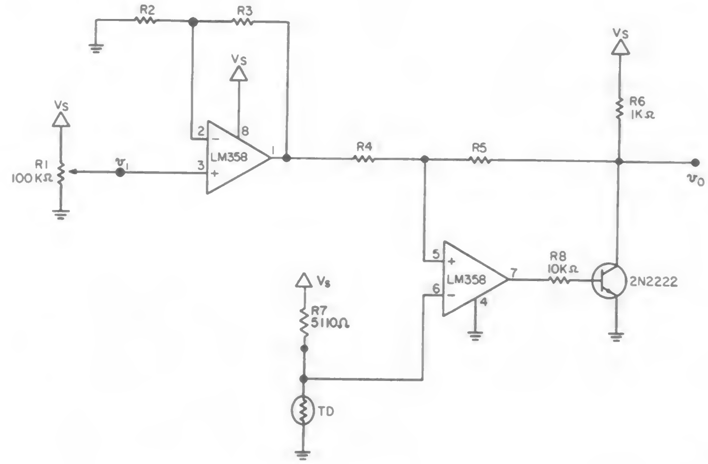


Figure 2
6.5-30 V Supply Voltage

Note: Any error on the 5.0 V regulator will be seen directly on v_O. This error can be reduced when setting the span by assuming that V equals the actual output of the regulator.

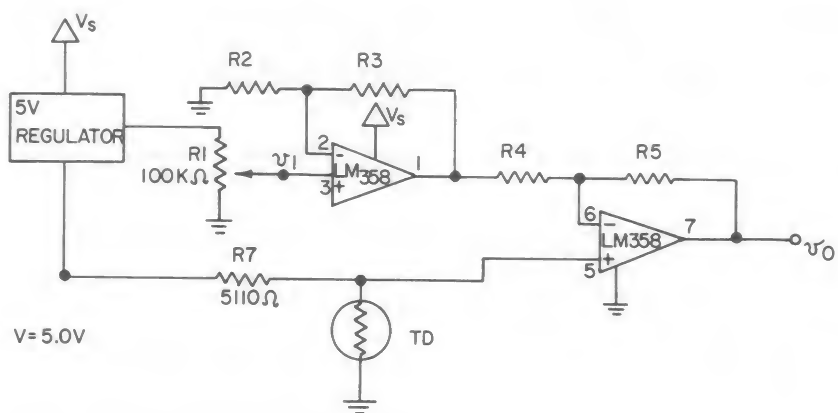
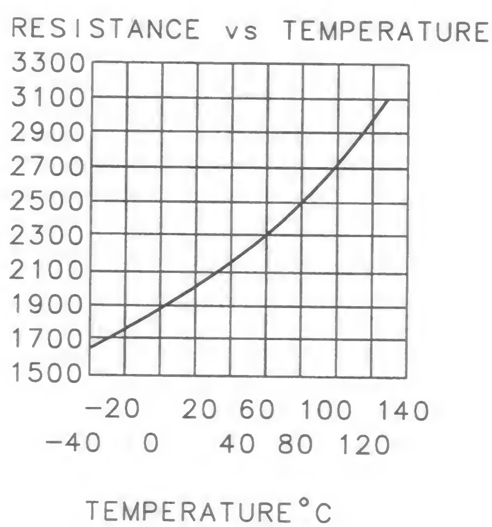


Figure 3
TD Series Resistance vs Temperature



ABSOLUTE MAXIMUM RATINGS

Operating temperature range	−40 to +150°C (−40 to +302°F)
Storage temperature range	−55 to +170°C (−67 to +338°F)
Voltage	10 VDC Continuous (24 hours)

Linearity
±2% (−25 to 85°C)
±3% (−40 to 150°C)
TD sensors can be linearized to within ±0.2%.

Repeatability
±1 Ω

ELECTRICAL INTERFACING

The high nominal resistance, positive temperature coefficient and linear sensitivity characteristics of TD Series temperature sensors simplify designing the electrical interface.

Figure 4 is a simple circuit that can be used to linearize the voltage output to within 0.2% or a ±0.4°C error over a range of −40° to +150°C (−40° to +302°F).

Figure 5 illustrates an interface for applications requiring a voltage that varies linearly with temperature. In the example shown, the current regulator sensor resistance can be affected by temperature, so only the temperature sensor should be exposed to thermal changes.

In some applications, it may be desirable to detect one particular temperature. Figure 6 illustrates one way this can be accomplished. In the comparator circuit shown, the potentiometer can be adjusted to correspond to the desired temperature.

Figure 4
Linear Output Voltage Circuit

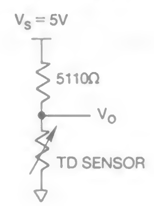


Table 1 – INTERCHANGEABILITY (with 1 μA maximum current)

Temperature	Resistance (Ohms)	Temperature	Resistance (Ohms)
−40°C (−40°F)	1584 ± 12 (1.9°C)	+60°C (140°F)	2314 ± 9 (1.1°C)
−30°C (−22°F)	1649 ± 11 (1.7°C)	+70°C (158°F)	2397 ± 10 (1.2°C)
−20°C (−4°F)	1715 ± 10 (1.5°C)	+80°C (176°F)	2482 ± 12 (1.4°C)
−10°C (14°F)	1784 ± 9 (1.3°C)	+90°C (194°F)	2569 ± 14 (1.6°C)
0°C (32°F)	1854 ± 8 (1.1°C)	+100°C (212°F)	2658 ± 16 (1.8°C)
+10°C (50°F)	1926 ± 6 (0.8°C)	+110°C (230°F)	2748 ± 18 (2.0°C)
+20°C (68°F)	2000 ± 5 (0.7°C)	+120°C (248°F)	2840 ± 19 (2.0°C)
+30°C (86°F)	2076 ± 5 (0.7°C)	+130°C (266°F)	2934 ± 21 (2.2°C)
+40°C (104°F)	2153 ± 6 (0.8°C)	+140°C (284°F)	3030 ± 23 (2.4°C)
+50°C (122°F)	2233 ± 7 (0.9°C)	+150°C (302°F)	3128 ± 25 (2.5°C)

Equation for computing resistance:

$R_T = R_O + (3.84 \times 10^{-3} \times R_O \times T) + (4.94 \times 10^{-6} \times R_O \times T^2)$

R_T = Resistance at temperature T

R_O = Resistance at 0°C

T = Temperature in °C

Figure 5
Simple Current Regulator Interface

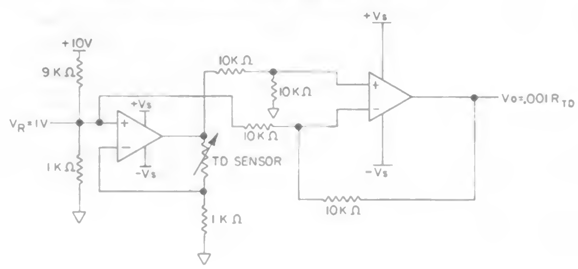
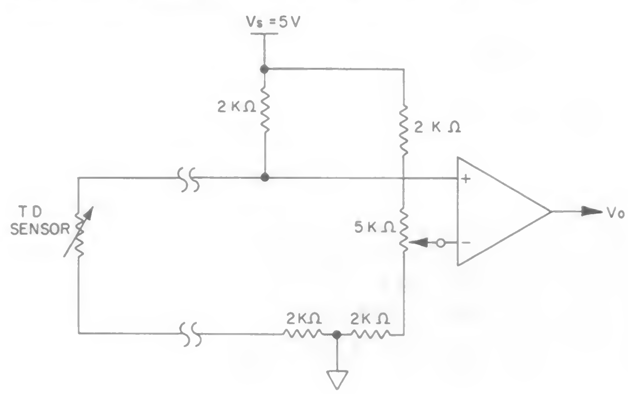


Figure 6
Adjustable Point (Comparator) Interface

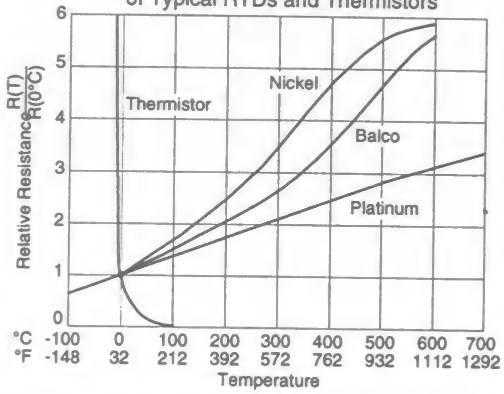


Reference/Index

PLATINUM RTD RESISTANCE VS. TEMPERATURE FUNCTION

PLATINUM is a precious metal with a very stable and near linear resistance versus temperature function. While intrinsically less sensitive than thermistors or other metals, thin film RTDs provide very high base resistance and high device sensitivity.

Relative Resistance Vs Temperature of Typical RTDs and Thermistors



Platinum's resistance versus temperature function is accurately modeled by the Callendar-Van Dusen equation. This equation uses constants A, B and C, derived from resistance measurements at 0°C, 100°C and 260°C.

Callendar-Van Dusen Equation:

$$R_T = R_0(1+AT+BT^2-100CT^3+CT^4)$$

R_T = Resistance (Ω) at temperature T (°C)
R_0 = Resistance (Ω) at 0°C
T = Temperature in °C

For T>0°C, the quadratic formula can be used to solve for Temperature as a function of measured resistance with the result:

$$0 = R_0BT^2+R_0AT+(R_0-R_T) \text{ implies...}$$

$$T_R = \frac{-R_0A+\sqrt{R_0^2A^2-4R_0B(R_0-R_T)}}{2R_0B}$$

Platinum RTDs are specified by resistance at 0°C, $\mathbf{R_0}$, and alpha, α, a term related to the temperature coefficient of resistance, or TCR. The Callendar-Van Dusen constants A, B and C are derived from alpha α and other constants, delta δ and beta β, which are obtained from actual resistance measurements. Common Callendar-Van Dusen constant values are shown in the table below:

CALLENDAR-VAN DUSEN CONSTANTS†

Alpha, α (°C^{-1})	.003750 ± .00003	.003850 ± .0001
Delta, δ (°C)	1.605 ± 0.009	1.4999 ± 0.007
Beta, β* (°C)	0.16	0.10863
A (°C^{-1})	3.81×10^{-3}	3.908×10^{-3}
B (°C^{-2})	-6.02×10^{-7}	-5.775×10^{-7}
C (°C^{-4})*	-6.0×10^{-12}	-4.183×10^{-12}

*Both $\beta = 0$ and $C = 0$ for T>0°C

The definitions of the Callendar Van Dusen constants: A, B, C, and alpha, delta and beta (α, δ and β), and their inter-relationships are given by the equations below. In all cases, the values of the constants and the fundamental accuracy and repeatability performance of an RTD is determined by the repeatability of the empirically measured resistance values:

$$R_0 \pm \Delta R_0 R_{100} \pm \Delta R_{100} \text{ and } R_{260} \pm \Delta R_{260}$$

$$A = \alpha + \frac{\alpha \cdot \delta}{100} \qquad B = \frac{-\alpha \cdot \delta}{100^2} \qquad C_{T<0} = \frac{-\alpha \cdot \beta}{100^4}$$

$$\alpha = \frac{R_{100} - R_0}{100 \cdot R_0} \qquad \delta = \frac{R_0 \cdot (1 + \alpha \cdot 260) - R_{260}}{4.16 \cdot R_0 \cdot \alpha}$$

$$\beta = \text{Constant for } T<0°C$$

TOLERANCE STANDARDS AND ACCURACY

IEC 751, the most commonly used standard for Platinum RTDs defines two performance classes for 100Ω, 0.00385 alpha Pt TRDs, **Class A** and **Class B**. These performance classes (also known as **DIN A** and **DIN B** due to DIN 43760) define tolerances on ice point and temperature accuracy. These tolerances are also often applied to Pt RTDs with ice point resistance outside of IEC 751's 100Ω assumption.

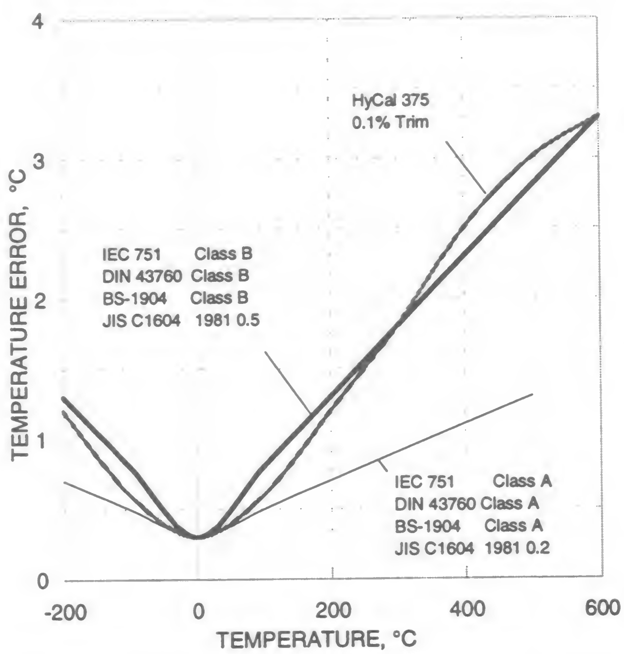
Class C and **Class D** (*each doubling the prior tolerance level*) are also used.

INTERNATIONAL STANDARDS

Standard	Comment	
IEC 751	Defines Class A and B performance for 100Ω 0.00385 alpha Pt RTDs.	
DIN 43760	Matches IEC 751.	
BS-1904	Matches IEC 751.	
JIS C1604	Matches IEC 751. Adds 0.003916 alpha.	
ITS-90	Defines temperature scale and transfer standard.	
Parameter	**IEC 751 Class A**	**IEC 751 Class B**
R_0	100Ω ± 0.06%	100Ω ± 0.12%
Alpha, α	.00385 ± .000063	.00385 ± .000063
Range	−200°C to 650°C	−200°C to 850°C
Res., R_T*	$\pm(.06+.0008\lvert T\rvert-2E\text{-}7T^2)$	$\pm(.12+.0019\lvert T\rvert-6E\text{-}7T^2)$
Temp, T**	$\pm(0.3+0.002\lvert T\rvert)$°C	$\pm(0.3+0.005\lvert T\rvert)$°C

*Units are Ωs. Values apply to 100Ω Pt RTDs only. Scale by ratio of the R_0s to apply to other ice point resistances.
*Applies to all 0.00385 alpha Pt RTDs independent of ice point, R_0.

PRTD TEMPERATURE ACCURACY



While IEC 751 only addresses 100Ω 385 alpha RTDs, its temperature accuracy requirements are often applied to such other platinum RTDs. However, manufacturers generally present both resistance-vs-temperature accuracies and temperature accuracies in tabular form for direct review.

The Callendar Van Dusen equation analytically addresses the tolerance and accuracy of a Pt RTD at any point within its operating temperature range independent of alpha and ice point resistance. The Resistance Limit-of-Error function (i.e. sensor resistance interchangeability as a function of temperature) can be calculated by taking the differential of the Callendar Van Dusen equation w.r.t. R_0, α and δ and applying the associated uncertainties. While an Expected (RMS) Error function can also be calculated, design engineers are typically interested only in the Limit-of-Error (LOE) function since it characterizes worst case behavior. The LOE function for resistance for T>0°C is:

$$\Delta R_{LOE} = \Delta R_0(1+AT+BT^2) + \Delta AR_0T + \Delta BR_0T$$

$$= \Delta R_0 + \Delta\alpha T + (\Delta\alpha\delta + \alpha\Delta\delta)\left[\frac{T}{100} + \frac{T^2}{100^2}\right]$$

Similarly, obtain the Temperature Limit-of-Error (i.e. temperature interchangeability) function using two approaches:

1. Multiply the derivative of R_T by the uncertainty ΔR_T

$$\Delta T_{T_1} = \Delta R_{T_1} \times \left.\frac{\partial R_T}{\partial T}\right|_{T_1}$$

2. Solve the Callendar Van Dusen equation for T, take the differential w.r.t. R_0, α and δ, then apply the appropriate uncertainties. In practice, it is "easier" to take the differential w.r.t. A and B and then apply ΔA and ΔB as calculated from α, $\Delta\alpha$, δ and $\Delta\delta$.

$$\Delta T_{LOE} = \frac{\Delta A}{2B} + \frac{A\Delta B}{2B^2} + \frac{\Delta B\sqrt{R_0^2A^2-4R_0B(R_0-R_T)}}{2R_0^2B^2} + \frac{[R_0^2A^2-4R_0B(R_0-R_T)]^{-\frac{1}{2}}\,[A\Delta AR_0^2+2R_0\Delta B(R_0-R_T)]}{2R_0B}$$

The second relationship could also be calculated in terms of the basic empirical data: $R_0\pm\Delta R_0$, $R_{100}\pm\Delta R_{100}$ and $R_{260}\pm\Delta R_{260}$.

RESISTANCE AND ACCURACY TABLES

PLATINUM RTD RESISTANCE-VS-TEMPERATURE				
Ice Point, Alpha Value & RTD Type	1000Ω 0.00375 Pt Thin Film	100Ω 0.00385 Pt Thin Film	100Ω 0.00385 Pt WW	100Ω 0.003902 Pt WW
Temperature °C	Resistance (Ω)			
-200	199.49	18.10	18.10	19.76
-180	284.87	26.81	26.81	28.01
-160	368.57	35.35	35.35	36.17
-140	450.83	43.75	43.75	44.27
-120	531.83	52.04	52.04	52.31
-100	611.76	60.21	60.21	60.31
-80	690.78	68.30	68.30	68.27
-60	769.01	76.32	76.32	76.22
-40	846.58	84.27	84.27	84.15
-20	923.55	92.16	92.16	92.08
0	1000.00	100.00	100.00	100.00
20	1075.96	107.79	107.79	107.92
40	1151.44	115.54	115.54	115.84
60	1226.44	123.24	123.24	123.76
80	1300.96	130.89	130.89	131.69
100	1375.00	138.50	138.50	139.61
120	1448.56	146.06	146.06	147.53
140	1521.63	153.57	153.57	155.45
160	1594.22	161.04	161.04	163.37
180	1666.33	168.46	168.46	171.29
200	1737.96	175.83	175.83	179.21
220	1809.11	183.16	183.16	187.14
240	1879.78	190.43	190.43	195.06
260	1949.96	197.67	197.67	202.98
280	2019.67	204.85	204.85	210.90
300	2088.89	211.99	211.99	218.82
320	2157.63	219.08	219.08	226.74
340	2225.89	226.12	226.12	234.66
360	2293.66	233.12	233.12	242.59
380	2360.96	240.07	240.07	250.51
400	2427.78	246.98	246.98	258.43
420	2494.11	253.83	253.83	266.35
440	2559.96	260.65	260.65	274.27
460	2625.33	267.41	267.41	282.19
480	2690.22	274.13	274.13	290.11
500	2754.63	280.80	280.80	298.04
520	2818.55	287.42	287.42	305.96
540	2881.99	294.00	294.00	313.88
560	2944.96	300.53	300.53	321.80
580	3007.44	307.01		
600	3069.44	313.44		
620	3130.96	319.83		
640	3191.99	326.18		
660	3252.55	332.47		
680	3312.62	338.72		
700	3372.21	344.92		
720	3431.32	351.08		
740	3489.95	357.18		
750	3519.09	360.22		

Sensor accuracy is a function of production tolerance and any additional calibration which the sensor may get. Calibration can improve the accuracy of an RTD by 10X over production tolerance.

The accuracy values in the table below apply to production tolerance tight trim RTDs with ice point tolerances of R_0 ±0.1%. The thin film values are for tight trim platinum RTDs. Both thin film and wire wound tight trim RTDs with 0.00385 alpha values meet IEC 751 Class B.

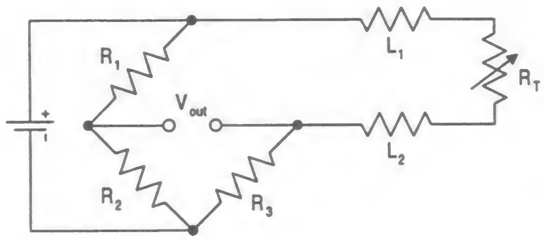
In qualifying volumes, RTDs can be laser trimmed for tight resistance interchangeability at any temperature between 0°C and 150°C or to an ice point resistance other than 100Ω or 1000Ω. Laser trimming also allows matching the resistance of RTD's with different alpha values at a target temperature.

ACCURACY* VS TEMPERATURE			
Ice Point, Alpha Value	1000Ω 0.00375	100Ω 0.00385	100Ω 0.003902
Temperature °C	±ΔResistance (Ω)		
-200	5.1	0.5	0.5
-100	2.4	0.3	0.3
0	1.0	0.1	0.1
100	2.2	0.2	0.2
200	4.3	0.4	0.4
300	6.2	0.6	0.6
400	8.3	0.8	0.8
500	9.6	1.0	1.0
600	10.4	1.2	1.2
Temperature °C	±ΔTemperature (°C)		
-200	1.2	1.2	1.2
-100	0.6	0.6	0.6
0	0.3	0.3	0.3
100	0.6	0.6	0.6
200	1.2	1.2	1.2
300	1.8	1.8	1.8
400	2.5	2.5	2.5
500	3.0	3.0	3.0
600	3.3	3.6	3.6

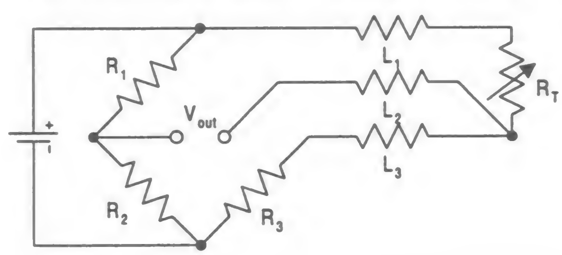
*Figures are for production tolerance tight trim RTDs.

TEMPERATURE CIRCUITS

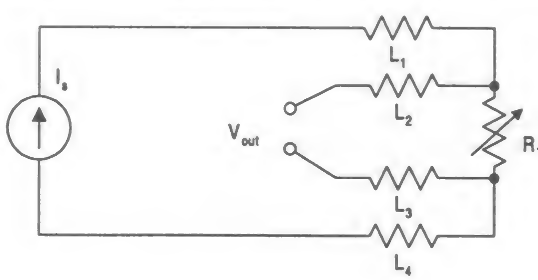
2-WIRE CIRCUIT: A Wheatstone bridge is the most common approach for measuring an RTD. As R_T increases or decreases with temperature, V_{out} also increases or decreases. Use an op-amp to observe V_{out}. Lead wire resistance, L_1 and L_2 directly adds to the RTD leg of the bridge.



3-WIRE CIRCUIT: In this approach, L_1 and L_3 carry the bridge current. When the bridge is in balance, no current flows through L_2 so no L_2 lead resistance is observed. The bridge becomes unbalanced as R_T changes. Use an op-amp to observe V_{out} and prevent current flow in L_2. The effects of L_1 and L_3 cancel when $L_1 = L_3$ since they are in separate arms of the bridge.

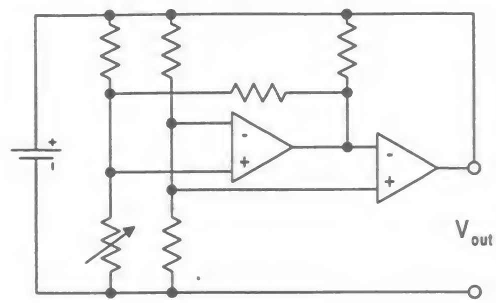


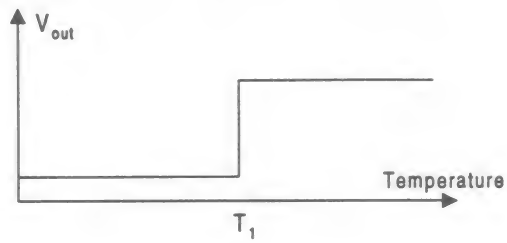
4-WIRE CIRCUIT: A 4-wire approach uses a constant current source to cancel lead wire effects even when $L_1 \neq L_4$. Use an op-amp to observe V_{out} and prevent current flow in L_2 and L_3.



TEMPERATURE SWITCH

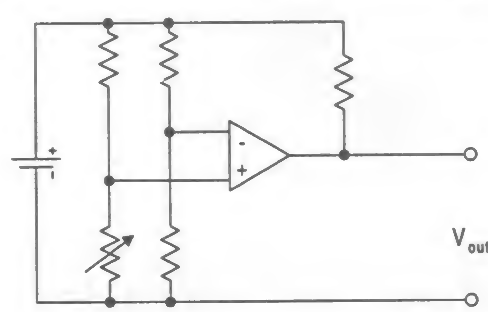
The following circuit causes an output voltage to rail whenever the temperature of the RTD rises above a fixed value T_1. The open-collector output simplifies the interfacing of this circuit with additional electronics.

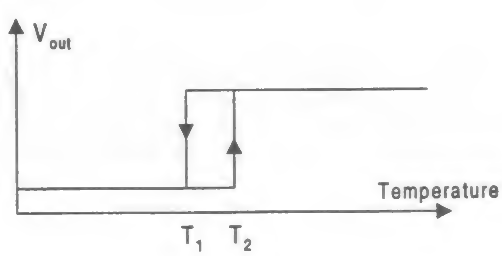




TEMPERATURE SWITCH WITH HYSTERESIS

The following circuit uses positive feedback from the output to self heat the RTD enough to develop a hysteresis in the behavior of the switch. Once on, the temperature must drop low enough to offset the self heating before the switch will disable.





HOT FILM ANEMOMETRY

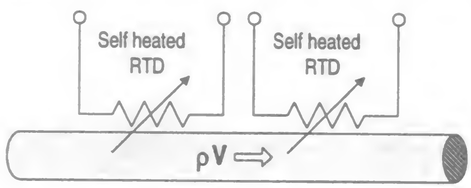
ANEMOMETRY balances heat gains with flow induced heat losses. Anemometers are constructed so that the dominant thermal loss for one or more heated RTDs is convective heat transfer to material flowing past the sensor.

Thermal Energy Gain = Σ Thermal Energy Losses

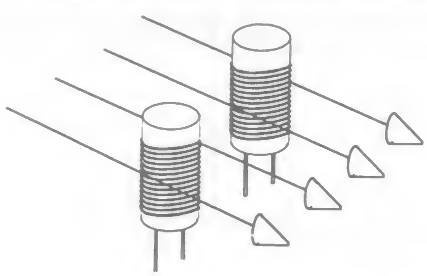
$$= \begin{bmatrix}\text{Radiative}\\ \text{Loss}\end{bmatrix} + \begin{bmatrix}\text{Conductive}\\ \text{Loss}\end{bmatrix} + \begin{bmatrix}\text{Convective}\\ \text{Loss}\end{bmatrix}$$

$$+ \begin{bmatrix}\text{Conductive}\\ \text{Loss to Flow}\end{bmatrix} \approx \begin{bmatrix}\text{Conductive}\\ \text{Loss to Flow}\end{bmatrix}$$

Capillary-Tube flow designs examine the differences in two self heated RTDs held at either equal temperature or equal electronic power input. Flowing material causes either a smaller thermal loss or a higher temperature at the down stream heater.

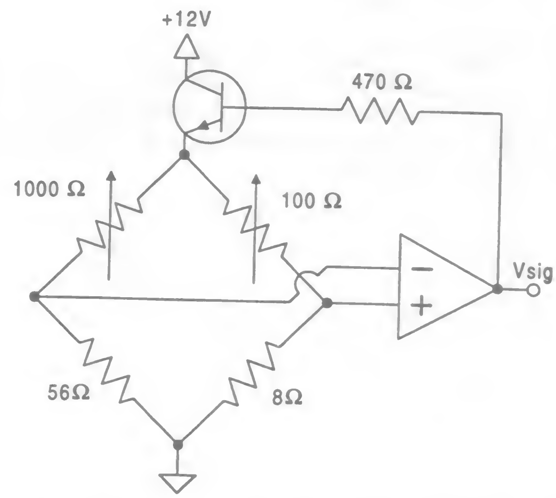


Immersion flow designs commonly use a self heated RTD and temperature compensation RTD with $T_{heated} = T_{amb} + \Delta T$, ΔT = constant. The velocity of the flowing material is then related to the heating energy, I^2R, required to keep ΔT = constant.



A common self heating immersion circuit uses two RTDs with very different ice point values in a bridge configuration. Current self heats the smaller RTD, $T = T_{amb} + \Delta T$, until its simultaneous increase in resistance, $R = R(T_{amb} + A\,\Delta T$, balances the bridge.

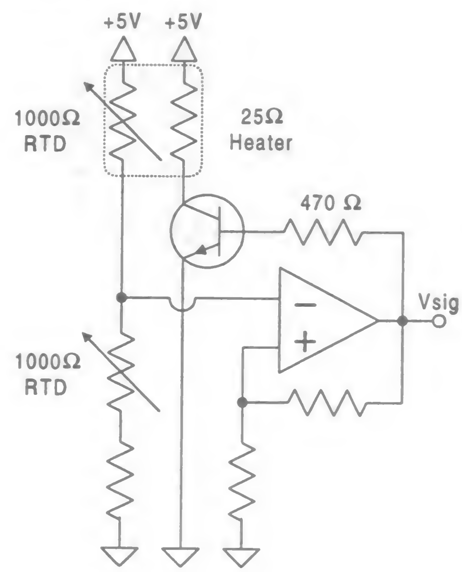
The large RTD provides temperature compensation. As T_{amb} increases, the large RTD's resistance increase causes further heating of the small RTD so that ΔT is held constant. The large difference in RTD ice point values insures that the large RTD does not self heat since most of the power is directed into the smaller RTD.



Temperature compensation allows calibration of flow velocity against V_{sig} (generally nonlinear) independent of the flow temperature, T_{amb}. If the temperature compensation is not good enough, i.e. $\Delta T = f(T_{amb})$, calibrate versus velocity and flow temperature. For optimal temperature compensation, matched sensitivities (over the T_{amb} range) are required, specifically:

$$\left.\frac{\partial R_{self\ heated}}{\partial T}\right|_{(T_{amb} + \Delta T)} = \left.\frac{\partial R_{temp\ comp}}{\partial T}\right|_{T_{amb}} \quad \text{For all } T_{amb}$$

If high heating power is required (such as in a liquid) use two RTDs and a separate heater. A separate heater also improves temperature compensation since identical RTDs with matched alphas can be used. However, the best ambient temperature compensation requires that the sensitivities rather than alpha values be matched.



HEAT CONDUCTION EQUATION AND RTD SELF HEATING

HEAT FLOW: Time response and other heat flow phenomena are governed by the Heat Conduction Equation. Solutions to the Heat Conduction Equation consist of a time independent final temperature distribution and a series sum of exponentially damped orthogonal functions which describe the evolution of the temperature distribution from the initial condition $f(x)$ to the final condition[1]. (Do not confuse the alpha used in this equation with the alpha used to describe an RTD's R-T curve.)

Heat Conduction Equation: $\alpha^2 \nabla^2 u = \dfrac{\partial u}{\partial t}$

$\alpha^2 = \dfrac{\kappa}{\rho s}$ Thermal Diffusivity (m^2/s)

$\kappa =$ Thermal Conductivity (J/s • m • °C)

$\rho =$ Density (kg/m^3)

$s =$ Specific Heat (J/°C)

Apply the Heat Conduction Equation to a thin film RTD mounted to a very thermally conductive, i.e. metal, surface, Figure 1 below. Since the RTD is very thin, approximate the problem as one-dimensional in x with a general solution $u(x, t)$ as shown below:

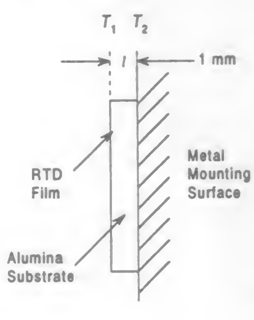


Figure 1

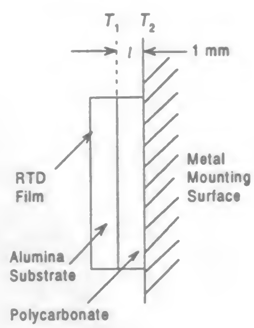


Figure 2

$$u(x,t) = (T_2 - T_1)\frac{x}{l} + T_1 + \sum_{n=1}^{\infty} b_n e^{-n^2\pi^2\alpha^2 t/l^2} \sin\left(\frac{n\pi x}{l}\right)$$

$$b_n = \frac{2}{l}\int_0^l \left[f(x) - (T_2 - T_1)\frac{x}{l} - T_1\right] \sin\left(\frac{n\pi x}{l}\right)$$

$f(x) =$ Temperature distribution at time t = 0.

SELF HEATING: Once heat is introduced into the RTD by resistive heating, the equation which defines thermal conductivity must be satisfied:

$$j_u = -\kappa \frac{\partial u(T)}{\partial x}$$

Applying the conductivity equation as a boundary condition on the general solution for the RTD-on-a-surface example, $u(x, t)$ results in the self heating relationship:

$$\frac{P}{A} = -\alpha^2 u'(0)$$

P = Thermal power dissipated in the RTD = $V_+^2/R(T)$

A = Surface area of the RTD

Yielding our result:

$$\frac{P}{A} = -\alpha^2 \frac{(T_2 - T_1)}{l} \text{ or } T_1 = \frac{lP}{\alpha^2 A} + T_2 = \frac{l V_+^2}{\alpha^2 A\, R(T)} + T_2$$

Example 1: Applying the result to a low thermal impedance situation, examine an HEL-700 at 0°C, with 0.254 mm (0.010 in) thick alumina substrate (diffusivity k = 38 W/m°C) and 1000 Ω ice point resistance. Here the self heating error calculated from a 2.3 mA current is negligible, less than 0.02°C.

Example 2: Examining a high thermal impedance situation, use the same RTD, encapsulated in a plastic or epoxy package such as a TO-92. Approximating this as an intervening 1 mm thick layer of polycarbonate with diffusivity of 0.199 W/m°C, the 2.3 mA current now generates a 12.4°C offset.

A plastic encapsulated RTD will exhibit significantly greater temperature offset error than the same un-encapsulated RTD when both are mounted to a surface (or environment) with good thermal conductivity. However, for air measurement, the opposite occurs as the table illustrates!

TEMPERATURE OFFSET IN STILL AIR

RTD Current	Ceramic SIP	Encapsulated
0.1 mA	<0.02°C	<0.02°C
1.0 mA	0.83°C	0.50°C

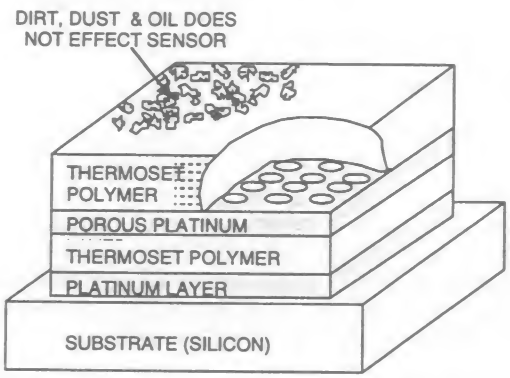
Conclusion: When the thermal conductivity of the sensor packaging is lower than the thermal conductivity of the environment being measured, then the sensor packaging can increase self heating. More importantly, lower operating currents always reduce or eliminate self heating errors.

[1] Note that the constant α used in the Heat Conduction equation is different from the alpha used to describe a platinum RTD.

HUMIDITY SENSOR THEORY AND BEHAVIOR

SENSOR CONSTRUCTION: Relative humidity sensors use an industrially proven thermoset polymer, three layer capacitance construction, platinum electrodes and except for high temperature versions (shown bottom), on-chip silicon integrated voltage output signal conditioning. (RHIC Sensor).

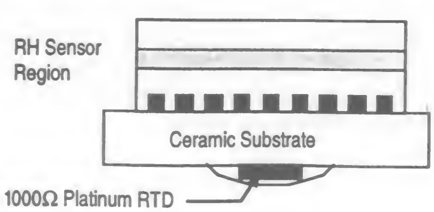
In operation, water vapor in the active capacitor's dielectric layer equilibrates with the surrounding gas. The porous platinum layer shields the dielectric response from external influences while the protective polymer over layer provides mechanical protection for the platinum layer from contaminants such as dirt, dust and oils. A heavy contaminant layer of dirt will slow down the sensor's response time because it will take longer for water vapor to equilibrate in the sensor.



TEMPERATURE & HUMIDITY EFFECTS: The output of all absorption based humidity sensors (capacitive, bulk resistive, conductive film, etc.) are affected by both temperature and %RH. Because of this, temperature compensation is used in applications which call for either higher accuracy or wider operating temperature ranges.

When temperature compensating a humidity sensor, it is best to make the temperature measurement as close as possible to the humidity sensor's active area, i.e. within the same moisture micro-environment. This is especially true when combining RH and temperature as a method for measuring dew point.

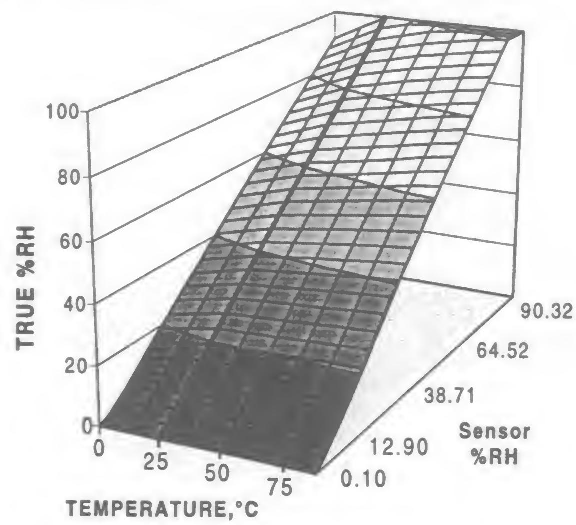
Industrial grade Humidity and Dew Point instruments incorporate a 1000 ohm Platinum RTD on the back of the ceramic sensor substrate for unmatched temperature compensation measurement integrity. No on-chip signal conditioning is provided in these high temperature sensors.



VOLTAGE OUTPUT: The RHIC sensor linear voltage output is a function of V_{supply}, %RH and temperature. The output is "ratiometric," i.e. as the supply voltage rises, the output voltage rises in the same proportion. A surface plot of the sensor behavior for temperatures between 0°C and 85°C is shown in the graph below. This surface plot is well approximated by a combination of two equations:

1. A "Best Fit Line at 25°C," or a similar, sensor specific equation at 25°C. The sensor independent "typical" Best Fit Line at 25°C (bold line in graph) is:
   $V_{out} = V_{supply}\,(0.0062\,(\%RH) + 0.16)$
   A sensor specific equation can be obtained from an RH sensor printout. The printout equation assumes V_{supply} = 5VDC and is included or available as an option on every sensor.

2. A sensor independent equation which corrects the %RH reading (from the Best Fit Line Equation) for temperature, T:
   True RH = (%RH)/(1.0546–.00216 T); T = °C
   Or True RH = (%RH)/(1.093–.0012 T); T = °F



The equations above match the typical surface plot (Best Fit Line at 25°C) or the actual surface plot (sensor specific equation at 25°C) to within the following tolerances:

±1% for T>20°C
±2% for 10°C<T<20°C
±5% for T<10°C

Our dewpoint instruments account for the sensor specific version of the surface plot directly via a look up table.

NOTE: Convert the observed output voltage to %RH values via the first equation before applying the second equation.

CONDENSATION AND WETTING

CONDENSATION occurs whenever the surface temperature of the sensor's active area drops below the ambient dew point of the surrounding gas. Condensation forms on the sensor (or any surface) even if the surface temperature only momentarily drops below the ambient dew point. Small temperature fluctuations near the sensor can unknowingly cause condensation to form when operating at humidity levels above 95%.

While quick to condense, water is slow to evaporate in high humidity conditions (i.e. when the surface temperature of the sensor is only slightly above the ambient dew point.) Because of this, a sensor's recovery period from either condensation or wetting is much longer than its normal time response. During recovery, the sensor outputs a constant 100% RH signal regardless of the ambient RH.

When an application calls for continuous monitoring of RH at humidity levels of 90% and above, take steps to avoid intermittent condensation. Some strategies are:

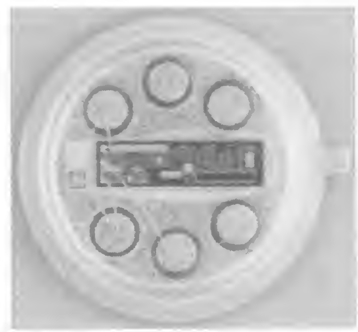
1. Maintain a good air mixing to minimize local temperature fluctuations.
2. The HIH-3602-A and -C use a sintered stainless steel filter to protect the sensor from splashing. A hydrophobic coating further suppresses condensation and wetting in rapidly saturating and de-saturating or splash prone environments.
3. Heat the RH sensor so that the active area is hotter than the local dew point. This can be done through an external heater or by self heating of the CMOS RH chip by operating it at a higher supply voltage.

NOTE: Heating an RH sensor above ambient temperature changes its calibration and makes it sensitive to thermal disturbances such as air flow. When contemplating such an approach, MICRO SWITCH recommends selecting an HIH-3602 type sensor and getting application technical support.

INTEGRATED SIGNAL CONDITIONING

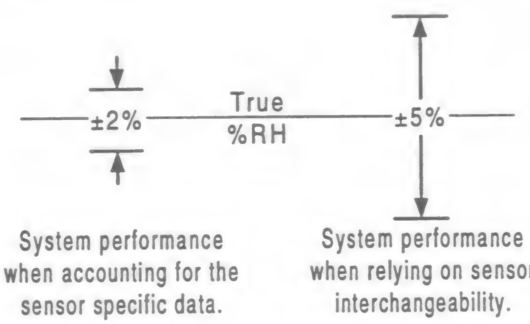
All RH sensors quickly recover from condensation or wetting with no shift in calibration. However, after 24 hour or longer exposures to either high >95% RH or continuous condensation, an upward shift of 2% to 3% RH may occur. This shift is repeatable and can be reversed by placing the sensor in a low 10% RH environment for a 10 hour period.

Silicon integrated humidity sensors (RHIC – relative humidity integrated circuit) incorporate signal conditioning circuitry on-chip with the sensing capacitor. These "RHIC" humidity sensors are laser trimmed so that at V_{supply} = 5 V, the output voltage typically spans 0.8V to 3.9V for the 0% RH to 100% RH range at 25°C. (Sensor specific calibration data printouts and best fit lines at 25°C are either included or available as an option on every sensor.)



The HIH-3602-C incorporates a RHIC humidity sensor, a 1000Ω platinum RTD and anti-static protection in a single TO-5 can.

RHIC based sensors are factory calibrated, micro-power devices with either individual calibration and/or good unit-to-unit interchangeability. These features help OEM manufacturers avoid in-house humidity calibration costs and extend battery life in portable instruments. Improved accuracy can be obtained by tuning system electronics to account an individual sensors Best Fit Line at 25°C.



HUMIDITY SENSOR CHEMICAL RESISTIVITY

Humidity sensors are routinely exposed to chemically active environments in the process of making moisture measurements. Chemical resistivity is an important differentiate between competing sensors and resulting system accuracy and reliability. To address this, MICRO SWITCH always uses proprietary, chemically resistive and thermally stable thermoset polymer as the active medium in all of its humidity and moisture sensors.

While following data reflects testing on the HIH-3602 sensor, the results are indicative of all other MICRO SWITCH moisture sensors. Protocols are severe relative to typical applications.

SATURATION AND RECOVERY PROTOCOL

- For each chemical tested, seven HIH-3602 sensors calibrated at 0% and 75.3% RH.
- A chemical saturation test was done by placing a drop of chemical on top of the sensor completely covering the hydrophobic filter for 175 minutes. A blow dryer was then applied to reduce the RH reading from 100% back down to room ambient.
- The sensors were again tested at 0% and 75.3% RH.
- The sensors are next allowed to recover under ambient RH for 60 hours.
- The sensors are again tested at 0% and 75.3% RH.

SATURATION & RECOVERY RESULTS

	Post Saturation		Post Recovery	
Chemical	Δ% at 0% RH	Δ% at 75.3% RH	Δ% at 0% RH	Δ% at 75.3% RH
Alcohol Isopropyl, 66%	+0.1	+1.13	+0.0	+1.83
Endo-Spor Hydrogen Peroxide	+0.46	−0.16	+0.4	−0.43
Glutaraldehyde Cydex Plus	+0.56	−2.13	+0.63	−1.63
Idophors Solution Westcodyne	+0.23	+0.16	+0.36	+0.93
Kleenaseptic	+3.13	+4.5	+2.96	+4.66
Quaternary Ammonium Virex 0.2%	+0.43	+0.2	+0.3	+0.8
Sodium Hypochlorite	+0.36	+0.6	+0.43	+1.53

LONG TERM VAPOR EXPOSURE PROTOCOL

- For each chemical tested, three HIH-3602 sensors were suspended 0.75 inches above the liquid chemical surface in a hermetically closed flask.
- Periodically, sensors were removed and tested at 0% RH and 75.3% RH.

Note that an entry of "F" denotes sensor failure. Blank entries indicate that the data was not taken.

LONG TERM EXPOSURE RESULTS

	Δ% RH Change over Exposure Time							
Chemical	89.0 hr		231.5 hr		400.0 hr		893.0 hr	
	0%	100%	0%	100%	0%	100%	0%	100%
Ammonia Hydroxide	F	F	F	F	F	F	F	F
Acetone	F*	F	F	F	F	F	F	F
Ethanol	F	F	F	F	F	F	F	F
Methanol	−1.9	25.1	−1.9	29.4	−3.7	35.0	−5.4	39.8
50% Ethanol + 50% Methanol	14.5	−17.4			7.8	−31.8	4.2	−22.0
Formaldehyde hyst. grade	0.8	0.0	1.5	−0.3	1.5	−1.4	1.9	−3.5
Formaldehyde neutral soln.	0.6	−0.7	1.2	−2.0	1.1	−3.5	1.6	−6.1
Formaldehyde norm & buff'd	0.4	0.8	1.2	−0.4	1.1	−1.3	1.5	−3.2
Benzene	−2.0	1.5	−1.1	−1.7	−0.3	−8.1	−1.1	−24.7
Toluene	−1.7	1.4	−0.8	0.4	0.4	0.0	−0.9	−4.3
Xylene	−1.7	1.5	−0.8	−0.2	−0.6	−0.7	−0.9**	0.0[2]
30% Benzene + 30% Toluene + 40% Xylene	−03	−1.2			−0.1	−6.0	−0.6	−16.1

*Sensors are resistant to acetone over shorter exposures.
**One sensor failed.

PSYCHROMETRICS & MOISTURE

MOISTURE measurements involve different terms and units. Moisture terms and units all fall under the area of psychrometrics, the study of water vapor concentration in air as a function of temperature and pressure. Selecting a moisture term depends on the application at hand.

Dew points and frost points are often used when the dryness of the gas is important, (moisture condensation from gas at low process temperatures must be avoided). Dew point is also used as an indicator of water vapor in high temperature processes, such as industrial drying.

Mixing ratios, volume percent, and specific humidity are usually used when water vapor is either an impurity or a defined component of a process gas mixture used in manufacturing. Mixing ratios are also used, like dew point, in industrial drying.

Relative humidity is most commonly used in HVAC applications where it directly impacts human comfort and indoor air quality issues. Relative humidity is also of interest to process control personnel as low RH can cause brittleness and static electricity problems, while high RH can cause swelling and clumping regardless of temperature.

MOISTURE TERMS, DEFINITIONS AND UNITS

Term	Definition	Unit
Absolute Humidity, (Vapor concentration)	$\frac{\text{Mass, Vapor}}{\text{Volume}}$	Grains/ft^3 Grams/m^3
Mixing Ratio	$\frac{\text{Mass, Vapor}}{\text{Mass, dry gas}}$	lb/lb, grains/lb, kg/kg, grams/kg
Relative Humidity	$\frac{\text{Mass, actual vapor}}{\text{Mass saturated vapor}}$ $\frac{\text{Actual vapor pressure}}{\text{Saturation vapor pressure}}$ $\frac{\text{Partial pressure, vapor}}{\text{Vapor pressure water}}$	%
Dew Point	Temperature of saturation (condensation)	°F or °C
Volume Ratio	$\frac{\text{Partial pressure, vapor}}{\text{Partial pressure, dry gas}}$	% by volume
Mass Ratio	Same as Mixing Ratio	PPM by weight, PPM_w
PPM by volume	$\frac{\text{Volume, vapor x } 10^6}{\text{Volume, dry gas}}$	PPM by volume, PPM_v
PPM by weight	$PPM_v \times \frac{\text{Mole weight of water}}{\text{Mole weight of carrier gas}}$	PPM by weight, PPM_w
Hygrometer	Instrument for measuring moisture in gas (from Greek hygros – wet, moist)	
Psychrometer	Instrument using wet/dry bulbs to measure moisture in gas (from Greek psychros – cold)	

PSYCHROMETRICS deals with the thermodynamic properties of moist gases while the term **Humidity** simply refers to the presence of water vapor in air or other carrier gas.

Psychrometrics concerns mixtures of water vapor and dry air. Much of it also applies to other carrier gases since the thermodynamic characteristics of water vapor are fairly independent of the carrier gas. In addition, as the composition of atmospheric air is fairly constant, dry air is treated as a homogeneous gas with a molecular weight of 28.9645. The molecular weight of water is 18.01528.

PARTIAL PRESSURE: The gas laws say that the total pressure of a gas mixture is the sum of the partial pressures of the constituent gases. Also the volume ratios of constituent gases are equal to the ratios of their partial pressures. For example, atmospheric pressure is the sum of the partial pressures of dry air and water vapor ($\rho_{atm} = \rho = \rho_a + \rho_W$).

WATER VAPOR PRESSURE: When a mixture of air and water vapor is in equilibrium with liquid water or with ice, it is considered to be saturated (RH = 100%). The water vapor saturation pressure over ice for the temperature range of −148 to 32°F is given by:

$$\ln(\rho_{WS}) = \frac{C_1}{T} + C_2 + C_3T + C_4T^2 + C_5T^3 + C_6T^4 + C_7\ln(T)$$

where $C_1 = -1.0214165E+04$ $C_5 = 3.5575832E-10$
$C_2 = -4.8932428E+00$ $C_6 = -9.0344688E-14$
$C_3 = -5.3765794E-03$ $C_7 = 4.1635019E+00$
$C_4 = 1.9202377E-07$

The saturation pressure over *liquid water* for the temperature range of 32 to 392°F is given by:

$$\ln(\rho_{WS}) = \frac{C_8}{T} + C_9 + C_{10}T + C_{11}T^2 + C_{12}T^3 + C_{13}\ln(T)$$

where $C_8 = -1.0440397E+04$ $C_{11} = 1.2890360E-05$
$C_9 = -1.1294650E+01$ $C_{12} = -2.4780681E-09$
$C_{10} = -2.7022355E-02$ $C_{13} = 6.5459673$

In both of the above equations,

ρ_{WS} = saturation pressure, psia
T = absolute temperature, °R = °F + 459.67

Reference/Index

SIMPLIFIED FORMULATIONS: The preceding equations are very accurate, but may be overly cumbersome for real time calculation. The following equations are less accurate, but are generally suitable for mid-range calculations as used in HVAC applications, for example.

For dew points higher than ice point:

$$e = [1.0007+P\times 3.46E-6] \times 6.1121 \times \exp\left(\frac{17.502 \times T}{240.9 + T}\right)$$

For dew points at or below ice point:

$$e = [1.0003+P\times 4.18E-6] \times 6.1115 \times \exp\left(\frac{22.452 \times T}{272.55 + T}\right)$$

e » p_w vapor pressure in millibars (one psi = 68.94745 millibars)
P = total pressure in millibars (1 atm = 1013.25 millibars, 14.696 psia)
T = temperature in °C(°F=°C×1.8+32)

RELATIVE HUMIDITY: the ratio of the partial vapor pressure to saturation vapor pressure at the dry bulb temperature:

$$RH = \frac{\rho_W}{\rho_{WS}} = \frac{\rho_{WS}(T_d)}{\rho_{WS}(T)}$$

where $\rho_{WS}(T_d)$ is saturation pressure at the dew point temperature and $\rho_{WS}(T)$ is saturation pressure at the dry bulb temperature. Relative humidity is moisture and temperature dependent but independent of total pressure. If dew point and dry bulb temperatures are known, then RH can be derived by calculating saturation vapor pressure for dew point and for dry bulb, then applying the RH definition above.

DEW POINT is the temperature at which a given sample of moist air is saturated. If the sample is cooled below dew point, then water vapor begins to condense. This phenomenon is the basis for various chilled sensor type dew point meters.

Frost Point: If measurements are made below the freezing point of water – that is if the indicated dew point is below the freezing point of water, then the equilibrium occurs at the vapor pressure of ice (not water), which is less than that of water. That is, the frost point is a bit higher than dew point.

If RH and dry bulb temperature are known, dew point can be derived by first calculating saturation pressure at the dry bulb temperature and then multiplying by the RH ratio to obtain ρ_W, the partial water vapor pressure. Now apply the following:

For the dew points in the range of 32 to 200°F:

$$T_d = C_{14} + C_{15}\alpha + C_{16}\alpha^2 + C_{17}\alpha^3 + C_{18}\rho_W^{0.1984}$$

And for dew points below 32°F:

$$T_d = 90.12 + 26.412\alpha + 0.8927\alpha^2$$

Where for both expressions:

T_d = dew point, °F	$\alpha = \ln(\rho_W)$, ρ_W in psia
C_{14} = 100.45	C_{15} = 33.193
C_{16} = 2.319	C_{17} = 0.17074
C_{18} = 1.2063	

VOLUME RATIO (also called mixing ratio by volume, or ppmv) is the ratio of water vapor volume to dry air volume (V_w/V_a). Because the volume ratios of mixed gases are the same as their partial pressures, volume ratio can be expressed as:

$$VR = \frac{\rho_W}{\rho_a};\ \rho = \rho_W + \rho_a$$

Because total pressure is the sum of partial pressures, the partial pressure of dry air can be readily derived (once vapor pressure is known), by measuring total pressure directly or by assuming one atmosphere (14.696 psia) total pressure. Multiply the ratio by one million to obtain ppmv (parts per million by volume).

HUMIDITY RATIO (also called mixing ratio by weight, or ppmw) is the ratio of the mass of water vapor to the mass of dry air. To calculate this, multiply the volume ratio by the ratio of the molecular weights:

$$W \equiv \frac{M_W}{M_a} = \frac{18.01528\ \rho_W}{28.9645\ \rho_a} = 0.62198\ \frac{\rho_W}{\rho_a}$$

The humidity ratio, in common use, is expressed in lb/lb, grains/lb, kg/kg, or g/kg. (There are 7000 grains in one pound.) Multiply the ratio by one million to obtain ppmw (parts per million by weight). An engineer may, for example, combine a humidity ratio value with the reading from a mass flow meter to calculate the mass of water vapor flowing through a dryer exhaust duct per unit time.

VOLUME PERCENT: equivalent to 100 times the mole fraction; the ratio of water vapor volume to total volume, V_w/V or $V_w/(V_w + V_a)$ expressed as a percentage. Like the volume ratio, it can be calculated in terms of partial pressures:

$$V\% = \frac{\rho_w}{\rho}; \rho = \rho_w + \rho_a$$

SPECIFIC HUMIDITY: normally expressed as a percentage, is the ratio of the mass of water vapor to the total mass, and can also be calculated in terms of the humidity ratio:

$$q = \frac{M_w}{M_w + M_a} = \frac{W}{1 + W}$$

ABSOLUTE HUMIDITY: (or water vapor density) is the ratio of the mass of water vapor to the total volume:

$$d_v = \frac{M_v}{V} = \frac{217.6 \times e}{T_{db} + 273.16}$$

d_v = absolute humidity expressed in grams H_2O per cubic meter of dry air and vapor mix (divide by 16,018.46 for lb/cu ft; divide by 2.28835 for grains/cu ft)

e = ρ_w vapor pressure in millibars (1 psi = 68.94745 millibars)

T_{db} = dry bulb temperature in °C (°F = °C × 1.8 + 32)

ENTHALPY: the measure of the energy content per unit mass. The enthalpy of a gas mixture equals the sum of the individual partial enthalpies of the components, (dry air and water vapor). In the English system, the specific enthalpy of dry air is assigned a value of zero at 0°F and standard atmospheric pressure. To calculate moist air enthalpy in Btu/lb dry air:

$$h = 0.240T + W(1061 + 0.444T)$$

where
T = dry bulb temperature, °F
W = humidity ratio of the moist air

STANDARD ATMOSPHERIC DATA: Normal atmospheric pressure variations have small effects on calculations that require a value for total pressure. However, at higher altitudes (Denver, for example), atmospheric pressure variations become significant. The following standard data is adapted from NASA. At sea level, standard temperature is 59°F and standard barometric pressure is 29.921 in. Hg.

STANDARD ATMOSPHERIC PRESSURE DATA

Altitude	Temp.	Pressure	
ft	°F	in Hg.	psia
0	59.0	29.921	14.696
500	57.2	29.38	14.430
1000	55.4	28.86	14.175
2000	51.9	27.82	13.664
3000	48.3	26.82	13.173
4000	44.7	25.82	12.682
5000	41.2	24.90	12.230

Reference: 1993 ASHRAE Handbook of Fundamentals, published by American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329. Telephone 404-636-8400.

NOTE: Most of the ASHRAE formulations are based on the thermodynamic temperature scale, which differs very slightly from practical scales (ITS-90) used for physical measurements. The boiling point of water is 211.95°F on this scale rather than the traditional 212°F. The slight difference is negligible for any practical application.

SATURATION VAPOR PRESSURES OF WATER P_w

Temperature (°C)	Saturation Vapor Pressure (mm Hg)	Temperature (°C)	Saturation Vapor Pressure (mm Hg)
-20	0.8	60	149.5
-10	1.9	70	233.8
0	4.6		
10	9.2		
20	17.5		
30	31.8	80	355.3
40	55.4	90	525.9
50	92.6	100	760.0

Reference/Index

GLOSSARY OF TERMS AND SEMICONDUCTOR TECHNOLOGY

Absolute Pressure Sensor - a sensor which measures input pressure in relation to zero pressure (a total vacuum on one side of the diaphragm).

Accuracy - a comparison of the actual output signal of a device to the true value of the input pressure. The various errors (such as linearity, hysteresis, repeatability and temperature shift)* attributing to the accuracy of a device are usually expressed as a percent of full scale output (Span).

* For a complete list of all the "errors that affect pressure sensor performance", see pages 104-105. (Also shows two ways to calculate the total error of a pressure sensor.)

Analog Output - an electrical output from a sensor that changes proportionately with any change in input pressure.

Auto Zeroing Technique - a method used to automatically set the null point on a pressure sensor. This is usually done by using a microprocessor to open a solenoid valve at a predetermined time interval. This references atmospheric pressure to both sides of the pressure sensor chip. The microprocessor reads the output voltage and makes that the new null point. This method is used to eliminate errors due to null offset and null temperature shift.

B.F.S.L. (Best Fit Straight Line) - a method for defining linearity. A straight line placed on a sensor output curve such that half the data points lie above and half below that line. The method for determining B.F.S.L. is the sum of least squares.

Bidirectional Differential Pressure Sensor - a differential pressure sensor allowing the greater input pressure to be applied to either pressure port.

Bridge Resistance - see Input Impedance and Output Impedance.

Burst Pressure - the specified pressure which will rupture the sensing element but not the sensor case.

Calibration - an act of modifying sensor output to improve output accuracy.

Calibration Curve - a graphical representation of the calibration record.

Capillary Tube Flow Design - examines differences in two self-heated RTDs held at equal temperature or equal input.

Chip - a die (unpackaged semiconductor device) cut from a silicon wafer, incorporating semiconductor circuit elements such as resistors, diodes, transistors, and/or capacitors.

Compensation - added circuitry or materials designed to counteract known sources of error.

Current sinking output (NPN) - load is connected between power supply and sensor. Current flows from the load through the sensor to ground (open collector).

Current sourcing output (PNP) - load is connected between sensor and ground. Current flows from the sensor through the load to ground (open emitter).

Dew Point - point at which a given sample of air is saturated. Related standards of measurement include Frost Point, and Ice Point.

Diaphragm - the membrane of material that remains after etching a cavity into the silicon sensing chip. Changes in input pressure cause the diaphragm to deflect.

Differential Pressure Sensor - a sensor which is designed to accept simultaneously two independent pressure sources. The output is proportional to the pressure difference between the two sources.

Diffusion - a thermochemical process whereby controlled impurities are introduced into the silicon to define the piezoresistors. Compared to ion implantation, it has two major disadvantages: 1) the maximum impurity concentration occurs at the surface of the silicon rendering it subject to surface contamination, and making it nearly impossible to produce buried piezoresistors; 2) control over impurity concentrations and levels is about one thousand times poorer than obtained with ion implantation.

Drift - an undesired change in output over a period of time, which is not a function of any input pressure change.

End Points - the pressure sensor outputs at specified upper and lower limits of the range.

End Point Linearity - see Terminal Base Linearity.

Enthalpy - a thermodynamic function of a system, equivalent to the sum of the internal energy of the system plus the product of its volume multiplied by the pressure exerted on it by its surroundings.

Error - the algebraic difference between the indicated value and the true value of the input pressure. Usually expressed in percent of full scale output, sometimes expressed in percent of the sensor output reading.

Error Band - the band of maximum deviation of the output values from a specified reference line or curve due to those causes attributable to the sensor. Usually expressed as "±% of full scale output." The error band should be specified as applicable over at least two calibration cycles, so as to include repeatability, and verified accordingly.

Excitation - the external electrical voltage and/or current applied to a sensor for its proper operation (often referred to as the supply current or voltage).

Frequency, Natural - the frequency of free (not forced) oscillations of the sensing element of a fully assembled sensor.

Frequency Output - an output in the form of frequency which varies as a function of the applied pressure.

Frost Point - if measurements are made below freezing point of water (if indicated dew point is below freezing point of water), then equilibrium occurs at vapor pressure of ice (not water). Vapor pressure of ice is less than that of water. The frost point is slightly higher than dew point. Often used when dryness of the gas is an important determination.

Full Scale Output (Span) - the algebraic difference between output curve end points (outputs at specified upper and lower output limits).

Gage Factor - a measure of the ratio of the relative change of resistance to the relative change in length of a resistive strain sensor (strain gage).

Gage Pressure - a form of differential pressure measurement in which atmospheric pressure is used as a reference.

IAQ - indoor Air Quality: calculated using CO_2 levels found in indoor air; high levels of CO_2 create an awareness of volatile organic compounds (VOCs) and bacteria.

Ice Point - Equal to 0°C (32°F), is the temperature at which pure water at 1 atm of pressure freezes. It is the physical phenomenon upon which the centrigrade temperature scale was originally based:

0°C = pure water, at 1 atm pressure, freezes

100°C = pure water, at 1 atm pressure, boills

Input Impedance - the impedance (presented to the excitation source) measured across the excitation terminals of a sensor.

Insulation Resistance - the resistance measured between specified insulated points on a sensor when a specified DC potential is applied at room conditions.

Ion Implantation - a process whereby impurity ions are accelerated to a specific energy level and impinged upon the silicon wafer. The energy level determines the depth to which the impurity ions penetrate the silicon. Impingement time determines the impurity concentration. Thus, it is possible to independently control these parameters, and buried piezoresistors are easily produced. Ion implantation is increasingly used throughout the semiconductor industry to provide a variety of products with improved performance over those produced by diffusion.

Laser Trimming (Automated) - a method for adjusting the value of thick film resistors using a computer-controlled laser system.

Leakage Rate - the maximum rate at which a fluid is permitted or determined to leak through a seal. The type of fluid, the differential pressure across the seal, the direction of leakage, and the location of the seal must be specified.

Least Squares Line - the straight line for which the sum of the squares of the residuals (deviations) is minimized. This method is used to calculate B.F.S.L. linearity.

Linearity - the closeness of an actual curve to a specified straightline. The degree to which the output of a linear device deviates from ideal performance.

Linearity (End Point) - see Terminal Base Linearity.

Linearity (Linearity Error) - the deviation of the sensor output curve from a specified straight line. Linearity error is usually expressed as a percent of full scale output.

Linearity (Terminal Base) - see Terminal Base Linearity.

Linear Output - an output which changes in proportion to the input.

Load Impedance - the impedance presented to the output terminals of a sensor by the associated external circuitry.

Maximum Excitation - the maximum value of supply voltage or current that can be applied to the sensor at room conditions without causing damage or performance degradation beyond specified tolerances.

MCTF (Mean Cycles to Failure) - the mean or expected cycles (pressure or force) of sensor operations at Full Scale until the sensor fails.

Metalization - the metal pattern deposited on the sensor chip (usually outside the diaphragm area) to permit electrical connections to be made to the chip. Aluminum is usually used, but has potential contamination problems (known as the "purple plague"), if not protected. MICRO SWITCH uses gold, which is impervious to almost everything.

Moisture Measurements - mix of ratios, volume percent, and specific humidity—used when water vapor is an impurity or a defined component of a process gas mixture used in manufacturing.

Natural Frequency - see Frequency, Natural

Null - the condition when the pressure on each side of the sensing diaphragm is equal.

Null Offset - the electrical output present, when the pressure is at null.

Null Temperature Shift - the change in null output value due to a change in temperature.

Operating Temperature Range - the temperature limits over which the pressure sensor is calibrated or specified.

Output Impedance - the impedance across the output terminals of a sensor presented by the sensor to the associated external circuitry.

Output Noise - the rms, peak-to-peak (as specified) AC component of a sensor's DC output in the absence of a change in input pressure.

Overforce - the maximum specified force which may be applied to the sensing element of a sensor without causing a permanent change in the output characteristics.

Overpressure - the maximum specified pressure which may be applied to the sensing element of a sensor without causing a permanent change in the output characteristics.

Piezoresistance - a change in resistance in a semiconductor, caused by an applied stress to the diaphragm.

Pressure Range - the pressure limits over which the pressure sensor is calibrated or specified.

Pressure Sensor - a device that converts an input pressure into an electrical output.

Proof Pressure - see Overpressure.

Quiescent Supply Current - the supply current being drawn when the pressure sensor is at null.

Rankine Scale - a scale of absolute temperature using Fahrenheit degrees, in which the freezing point of water is 491.69° and the boiling point of water is 671.69°, measure of thermodynamic temperature.

Rated Electrical Characteristics

Supply Voltage: - range of voltage over which the sensor is guaranteed to operate within performance specifications.

Supply Current: - corresponds to current drain on the Vs terminal. Supply current is dependent upon the supply voltage.

Output Voltage: - saturation voltage (VSAT) of the output transistor. Voltage which appears at the output due to inherent voltage drop of the output transistor in the ON condition.

Output Current: - maximum output current at which the sensor is guaranteed to operate within performance specifications.

Output Leakage Current: - maximum current which remains flowing through the output transistor when it is turned OFF.

Output Switching Time: - time required by the output transistor to change from one logic state to the other after a change has been initiated. This specification applies only to conditions specified on the product drawing.

Ratiometric (Ratiometricity Error) - at a given supply voltage, sensor output is a proportion of that supply voltage. Ratiometricity error is the change in this proportion resulting from any change to the supply voltage. Usually expressed as a percent of full scale output.

Regulated Voltage - desired output voltage is maintained regardless of normal change to input or output load.

Repeatability - the deviation in output readings for successive application of any given input pressure (with other conditions remaining constant).

Resolution - the magnitude of output step changes as the pressure is continuously varied over the range. This term applies primarily to potentiometric sensors. Resolution is best specified as average and maximum resolution. Usually expressed in percent of full scale output.

Response Time - the length of time required for the output of a sensor to rise to a specified percentage of its final value as a result of a step change of input pressure.

Room Conditions - ambient environmental conditions under which sensors must commonly operate, which have been established as follows:
(a) Temperature: 25 ± 10°C (77 ± 18°F).
(b) Relative humidity: 90% or less.
(c) Barometric pressure: 26 to 32 inches Hg.
Note: Tolerances closer than shown are frequently specified for sensor calibration and test environments.

Sensing Element - that part of a sensor which responds directly to changes in input pressure.

Sensitivity - the ratio for change in sensor output to a change in input.

Sensitivity Shift - a change in sensitivity resulting from an environmental change such as temperature.

Span - the algebraic difference between limits of the pressure range.

Stability - the ability of a sensor to retain its performance characteristics for a relatively long period of time. Unless otherwise stated, stability is the ability of a sensor to reproduce output readings obtained during its original calibration, at room conditions, for a specified period of time. It is typically expressed as "within ±% of full scale output for a period of XX months.

Storage Temperature Range - the minimum and maximum specified temperature which may be applied to the pressure sensor without causing a permanent change in the output characteristics.

Strain Gage - a sensing device providing a change in electrical resistance proportional to the level of applied stress.

Temperature calibrations - Single Point: calibration at 0°C (Ice Point); Two Point: calibration at 0°C and 100°C; Three Point: calibration at 0°C, 100°C, and 250°C.

Temperature Error - the maximum change in output, at any input pressure within the specified range, resulting from a change in temperature.

Terminal Base Linearity - T.B.L. (End Point Linearity)—a method of defining linearity.The maximum deviation of any data point on a sensor output curve from a straight line drawn between the end data points on that output curve. (T.B.L. is approximately twice the magnitude of B.F.S.L.).

Thermodynamic Temperature Scale - varies slightly from Fahrenheit: 211.95° vs. 212°F.

Thick-Film - technology using silk screened pastes to form conductor, resistor, thermistors, and insulator patterns; screened onto the substrate (usually ceramic) and cured by firing at elevated temperatures.

Thin Film - a technology using vacuum deposition of conductors and dielectric materials onto a substrate (frequently silicon) to form an electrical circuit.

Typical - (as used herein): refers to the target value or where a range is given, represents an estimate of where 2/3 of the total population of several production runs would be.

Unidirectional Differential Pressure Sensor - a differential pressure sensor requiring the greater input pressure to be applied to a specified pressure port.

VOCs-Volatile Organic Compounds - bioeffluents (bacterial and organic compounds) found in indoor air as CO_2 levels rise.

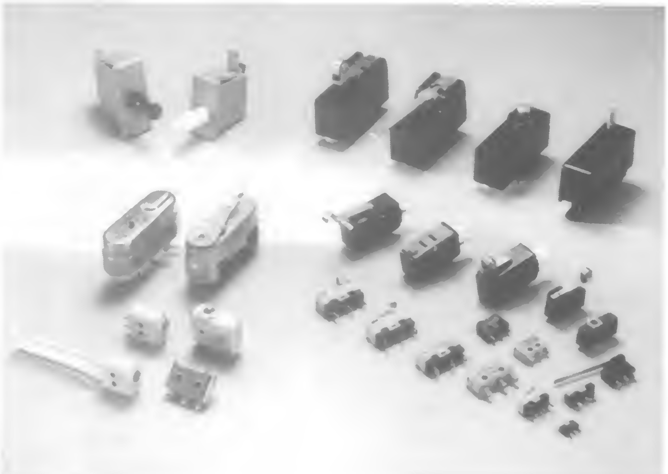
PRESSURE CONVERSION CHART

PRESSURE CONVERSION CHART

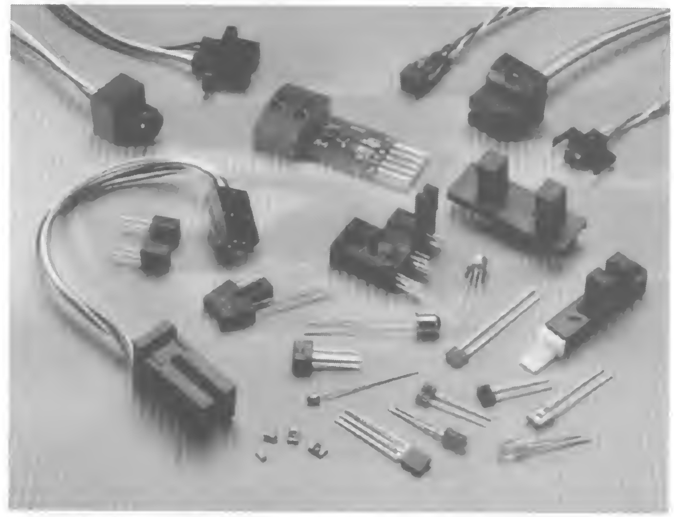
psi	in. H_2O	in. Hg	cm H_2O	mm Hg	bar	mbar	kPa
0.01	0.2768	0.0204	0.7031	0.5171	0.0007	0.6895	0.0690
0.02	0.5536	0.0407	1.406	1.034	0.0014	1.379	0.1379
0.03	0.8304	0.0611	2.109	1.551	0.0021	2.068	0.2068
0.04	1.107	0.0814	2.812	2.068	0.0028	2.758	0.2758
0.05	1.384	0.1018	3.512	2.586	0.0034	3.447	0.3447
0.06	1.661	0.1222	4.218	3.103	0.0041	4.137	0.4137
0.07	1.938	0.1425	4.922	3.620	0.0048	4.826	0.4826
0.08	2.214	0.1629	5.625	4.137	0.0055	5.516	0.5516
0.09	2.491	0.1832	6.328	4.654	0.0062	6.205	0.6205
0.10	2.768	0.2036	7.031	5.171	0.0069	6.895	0.6895
0.20	5.536	0.4072	14.06	10.34	0.0138	13.79	1.379
0.30	8.304	0.6108	21.09	15.51	0.0207	20.68	2.068
0.40	11.70	0.8144	28.12	20.68	0.0276	27.58	2.758
0.50	13.84	1.018	35.12	25.86	0.0345	34.47	3.447
0.60	16.61	1.222	42.18	31.03	0.0414	41.37	4.137
0.70	19.38	1.425	49.22	36.20	0.0483	48.26	4.826
0.80	22.14	1.629	56.25	41.37	0.0552	55.16	5.516
0.90	24.91	1.832	63.28	46.54	0.0620	62.05	6.205
1.0	27.68	2.036	70.31	51.71	0.0690	68.95	6.895
2.0	55.36	4.072	140.6	103.4	0.1379	137.9	13.79
3.0	83.04	6.108	210.9	155.1	0.2068	206.8	21.37
4.0	110.7	8.144	281.2	206.8	0.2758	275.8	27.58
5.0	138.4	10.18	351.5	258.6	0.3447	344.7	34.47
6.0	166.1	12.22	421.8	310.3	0.4137	413.7	41.37
7.0	193.8	14.25	492.2	362.0	0.4826	482.6	48.26
8.0	221.4	16.29	562.5	413.7	0.5516	551.6	55.16
9.0	249.1	18.32	632.8	465.4	0.6205	620.5	62.05
10.0	276.8	20.36	703.1	517.1	0.6895	689.5	68.95
14.7	406.9	29.93	1034.0	760.2	1.014	1014	101.4
15.0	415.2	30.54	1055.0	775.7	1.034	1034	103.4
20.0	553.8	40.72	1406.0	1034	1.379	1379	137.9
25.0	692.0	60.80	1758.0	1293	1.724	1724	172.4
30.0	830.4	61.08	2109.0	1551	2.068	2068	206.8
40.0	1107	81.44	2812.0	2068	2.758	2758	275.8
50.0	1384	101.8	3515.0	2586	3.447	3447	344.7
100.0	2768	203.6	7031.0	5171	6.895	6895	689.5
150.0	4152	305.4	10550.0	7757	10.34	10340	1034
200.0	5538	407.2	14060.0	10340	13.79	13790	1379
250.0	6920	608.0	17580.0	12930	17.24	17240	1724

Other MICRO SWITCH Product Catalogs

Honeywell MICRO SWITCH division's reputation as an innovator in the design and manufacture of quality position sensing and manual control products spans 40 years. Shown is a cross-section of the many varieties. This broad selection offers a wide range of technologies, sizes, actuation means, circuitries, electrical capacities, and terminations, for in-plant and original equipment needs. Contact your nearest MICRO SWITCH Sales Office or Authorized Distributor for complete catalog information. For direct assistance, contact MICRO SWITCH, Freeport, IL 61032, or phone 1-800-537-6945.

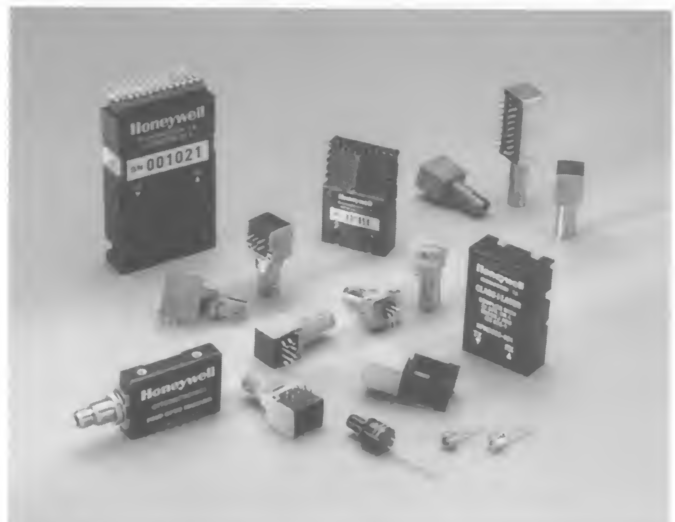


BASIC SWITCHES
These listings include standard size basics, miniature, subminiature, hermetically sealed, and high temperature switches. The precision snap-action mechanisms are offered with wide variety of actuators and operating characteristics. MICRO SWITCH basic switches are ideal for applications requiring compactness, light weight, accurate repeatability and long life. **Catalog 10.**



INFRARED PRODUCTS
Optoelectronics is the integration of optical principles and semiconductor electronics. Optoelectronic components are reliable, cost effective sensors. Standard infrared emitting diodes (IREDs), sensors and assemblies are covered. **Catalog E26.**

SOLID STATE SENSORS
Hall effect position and vane sensors, metal detecting proximity sensors, and current sensors are available in various sizes and terminations. Reliability, high speed, long life and direct compatibility with other electronic circuitry combine to provide the solutions to your solid state sensor needs. **Catalog 20.**



FIBER OPTIC LAN PRODUCTS
The Fiber Optics group specializes in the design, development and manufacture of active optoelectronic components and subassemblies for the short-haul fiber optic datacom market. Active fiber optic products are compatible with the majority of standard multimode fiber optic connectors and cables now available in industry.

Custom fiber optic products are also available. They are standard products with special testing, selection, documentation and/or minor physical changes to meet special requirements. New innovative products are constantly in development. **Catalog 27.**

Other MICRO SWITCH products

LIMIT AND ENCLOSED SWITCHES
MICRO SWITCH offers the world's most advanced line of heavy duty limit switches and a wide selection of application proven enclosed switches (precision snap-acting switches sealed in rugged metal housing). Sealed versions keep out moisture and other contaminants. Explosion-proof types are designed for use in hazardous locations. **Industrial Catalog.**

PROXIMITY SENSORS
Proximity sensors detect the presence of metals or react to a magnetic field. Cylindrical, cannister, and limit switch style housings provide application versatility. Their high speed operation keeps pace with production. Models are available for operation at AC line voltage or wide range VDC. Optional LED indicators signal on-off conditions. **Industrial Catalog.**

PHOTOELECTRIC SENSORS
MICRO SWITCH has a complete offering of modulated LED and incandescent controls. These devices detect opaque or translucent material at long or short range. Single unit retroreflective and separate emitter/receiver styles fill a variety of application requirements. High intensity models penetrate foggy, dusty, and other poor visibility conditions. Scanning capability ranges from a fraction of an inch to hundreds of feet. **Industrial Catalog.**

INDUSTRIAL SAFETY PRODUCTS
Honeywell is the worldwide leader in advanced switching and sensing technology–especially in the area of industrial machine safety. We offer electronic and electromechanical safety components for safety applications in all categories of risk. Honeywell products meet or exceed European machine safety standards and have been approved (CE, BG, INRS) for use in Europe for more than 25 years. Our products are designed to meet all applicable OHSA and ANSI standards as well. **Industrial Safety Products Catalog (107005)**

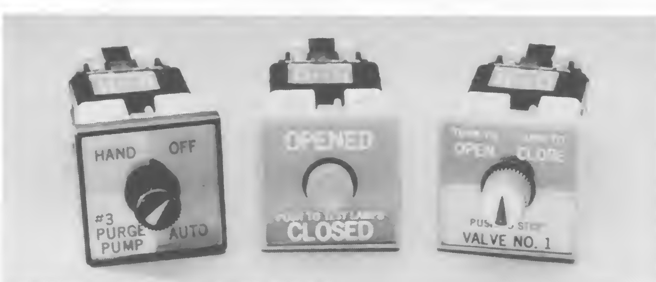
ULTRASONIC PRECISION PROXIMITY SENSORS
Ultrasonic position sensors solve tough sensing problems, detecting targets made of practically any material. They work in dry, dusty environments. **Industrial Catalog.**

Reference/Index

Other MICRO SWITCH products

ENVIRONMENTALLY PROTECTED SWITCHES
Rugged, high performance designs; environment-proof or hermetically sealed. A complete selection includes miniature limit switches, miniature and standard size basic switches, sealed, toggle switches and the highest quality lighted pushbuttons. **Catalog 80.**

MANUAL CONTROL SWITCHES
Whether you're prototyping a new design or planning to face-lift an existing panel, you'll benefit by considering the wide selection of pushbuttons, indicators, toggles, rockers, paddles, rotary selectors and interlock switches available from MICRO SWITCH. Developed with adherence to good human factors principles, these products aid the designer by offering almost limitless options in visual display techniques, operators, and arrangement of components. Many are military qualified. **Catalog 30.**



MULTI-LIGHT OILTIGHT CONTROLS
Featuring the contemporary square appearance and lighted display, the CMC family offers a wide selection of industrial pushbuttons, selectors and indicators. Contact blocks include heavy duty, standard or electronic duty, plus the four plunger adapter kit to use all four points on the cam. **Multi-light Oiltight Controls Catalog.**

SMART DISTRIBUTED SYSTEM
The Smart Distributed System is a bus system for intelligent sensors and actuators that streamlines the system installation process and empowers your inputs and outputs to operate at levels you never though possible. Over a single 4-wire cable, Smart Distributed System can interface up to 126 individually addressable devices. These intelligent sensor and actuator devices do much, much more than just turn on and off.

SYSTEM DIAGNOSTICS
The Smart Distributed System is based on the CAN Protocol. CAN is a full function network protocol that provides both message checking and correction to insure communication integrity.

DEVICE DIAGNOSTICS
Many of the Smart Distributed System devices have special diagnostics designed into them. For instance, some of the photoelectric controls can send warning messages if their lenses get dirty or they are out of alignment. Other diagnostics will be coming in the future.

DEVICE FUNCTIONS
All Smart Distributed System devices are intelligent and can be setup, via the Activator or PC base control programs, to perform high-level functions that non-System devices simply cannot do. Using the System device functions you can off-load rudimentary control functions to the devices, allowing the host to concentrate on errors if they occur. Smart Distributed System device functions include:

- Normally-open or normally-closed (switches and sensors)
- Light operate or dark operate (photoelectric controls)
- On-delay
- Off-delay
- Motion or jam detection
- Batch counter
- Number of operations count
- Number of power cycles count

TRULY OPEN DISTRIBUTED MACHINE CONTROL
The Smart Distributed System is uniquely and completely open. It works with the PLC or PC control device of your choice. That makes the Smart Distributed System completely compatible with your present control system or whatever control system you have in mind for the future. In fact, no other distributed machine control system offers as much flexibility or growth potential. The Smart Distributed System protocol will even accommodate peer-to-peer communication.

MORE DEVICE SELECTION FOR GREATER FLEXIBILITY
Many manufacturers of industrial control devices have become part of Smart Distributed System simply by integrating our CAN-based chips or by utilizing off-the-shelf interface devices. The Smart Distributed System can be easily integrated into your control system, allowing you to choose the equipment and manufacturers that best match your application.

Alphabetical Product/Page Cross-Reference Index

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